FAUNAL CHANGE OF LATE MIOCENE AFRICA AND EURASIA: MAMMALIAN FAUNA FROM THE NAMURUNGULE FORMATION, SAMBURU HILLS, NORTHERN KENYA

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ABSTRACT The Namurungule Formation yields a large amount of mammals of a formerly unknown and diversified vertebrate assemblage of the late Miocene. The Namurungule Formation has been dated as approximately 7 to 10 Ma. This age agrees with the mammalian assemblage of the Namurungule Formation. Sedimentological evidence of this formation supports that the Namurungule Formation was deposited in lacustrine and/or fluvial environments. Numerous equid and bovid remains were found from the Namurungule Formation. These taxa indicate the open woodland to savanna environments. Assemblage of the Namurungule Fauna indicates a close similarity to those of North Africa, Southwest and Central Europe, and some similarity to Sub-Paratethys, Siwaliks and East Asia faunas. The Namurungule Fauna was the richest among late Miocene (Turolian) Sub-Saharan faunas. From an analysis of Neogene East African faunas, it became clear that mammalian faunal assemblage drastically has changed from woodland fauna to openland fauna during Astaracian to Turolian. The Namurungule Fauna is the forerunner of the modern Sub-Saharan (Ethiopian) faunas in savanna and woodland environments.

Key Words: Mammal; Neogene; Miocene; Sub-Saharan Africa; Kenya; Paleobiogeography; Paleoecology; Faunal turnover.

INTRODUCTION

I. Scope of Study

1. Late Miocene Gap of Sub-Saharan Mammalian Evolution

In evolutionary paleontology, the late Miocene is an important age for mammalian evolution. The modern mammalian fauna appeared from this age in Eurasia. In Sub-Saharan Africa, the assemblage of the late Miocene mammalian faunas was very poor, and these faunas were represented by only the Ngorora upper E, Ngeringerowa and Nakali faunas before the commencement of the Japan and Kenya joint expedition to the Samburu Hills, northern Kenya. Because of this incompleteness of the late Miocene East African faunas, it is very difficult to compare with Eurasian and Sub-Saharan faunas of this age.

2. Hominoid Fossil

In the human evolution, it is very important to study the origin of hominid and paleoenvironments of hominoids evolution in the Sub-Saharan Africa, because there is a large possibility that the fossil evidence for branching of the Hominidae from the

Hominoidea will be discovered there. Furthermore, the paleoenvironmental change such as savannitisation seems to affect on the human evolution. The Namurungule Fauna is very important, from the viewpoint of the environmental change onto the hominoid evolution during the late Miocene. A hominoid fossil (Samburu large Hominoid) was discovered from the Namurungule Formation and it seems to be a possible common ancestor of the Hominidae and the African Apes (*Pan* and *Gorilla*) or the direct ancestor of the African Apes (Ishida et al, 1984).

3. Excavation of Samburu Hills, Northern Kenya (1980-1988)

Since the beginning of this century, many excavation teams visited and studied in Sub-Saharan Cenozoic sites, because Charles Darwin (1871) suggested that "*it is somewhat more probable that our early progenitors lived on the African continent than elsewhere.*" in "*The Descent of Man and Selection in Relation to Sex*" (Chapter VI). Japan and Kenya excavation team (supported by the Japanese Ministry of Education, Science and Culture with its Grant-in-Aid for Overseas Scientific Survey) started to study Miocene sites in northern Kenya since 1980. The author joined this team as a vertebrate paleontologist since 1981. The excavation in the Samburu Hills was started from 1982 and we found new rich vertebrates sites including hominoid fossils from the Namurungule Formation. The author was a junior representative of the branch in Nairobi, Kenya of the Japan Society for Promotion of Science and a research student of the National Museums of Kenya from April, 1983 to March, 1984. And he investigated the middle to late Miocene Sites yielding vertebrate fossils of Kenya in 1983. And he has been also a member of the joint excavation team of Japan and Kenya as a vertebrate paleontologist from 1984 to 1986. This team excavated the Samburu Hills area in 1982 (Ishida, 1984), 1984, 1986, 1988 and Japanese team excavated the late Miocene Lake Albert area of Zaire in 1989 (Ishida & Yasui eds., 1992).

II. Historical View of Mammalian Interchange between Africa and Eurasia

The Mesozoic mammalian remains of Africa were found from the late Triassic or early Jurassic of Lesotho (Clemens et al., 1979), the late Jurassic of Tanzania (Clemens et al., 1979), the middle Jurassic to late Cretaceous of Morocco (Sigogmeau-Russell et al. 1988) and the early Cretaceous of Cameroon (Jacobs et al., 1988). Eutherian mammals appeared in Africa from the late Paleocene. In the Paleocene and Oligocene, mammalian remains were found only from north and west Africa excluding Sub-Saharan area. After the Oligocene, a great number of mammalian fossil sites in Sub-Saharan Africa have been described and phylogeny of these taxa has been studied (reviewed in Maglio & Cooke eds., 1978). Many mammalian taxa immigrated into Sub-Saharan Africa. A great deal of studies have been published about the Neogene mammalian interchange between Africa and Eurasia (Thenius, 1972; Coryndon & Savage, 1973; Maglio, 1978; Thomas, 1979, 1981, 1984; Howell, 1980; Thomas et al., 1982; Adams et al., 1983; Savage & Russell, 1983; Bernor, 1983, 1986; Bernor & Hussain, 1985; Tassy, 1986).

III. Materials

The materials from the Samburu Hills are housed at the National Museums of Kenya (KNM) (Nairobi). The materials offered in this study were compared to African and Eurasian fossil mammals housed at the National Museums of Kenya (KNM) (Nairobi), British Museum (Natural History) (London), Laboratoire de Paléontologie, Muséum National d'Histoire naturelle (Paris), Laboratoire de Paléontologie des Vertébrés et de Paléontologie Humaine, Université de Paris VI (Paris), Department des Sciences de la Terre, Université Claude-Bernard, Lyon I (Villeurbanne) and Bayerischen Staatssammlung für Paläontologie und historische Geologie (München).

GEOLOGICAL BACKGROUND

I. Geology and Geochronology of the Namurungule Formation

The Samburu Hills form a belt about 30 km wide and about 80 km long trending in a north-southerly direction and beside the western wall of Suguta valley (Fig. 1).

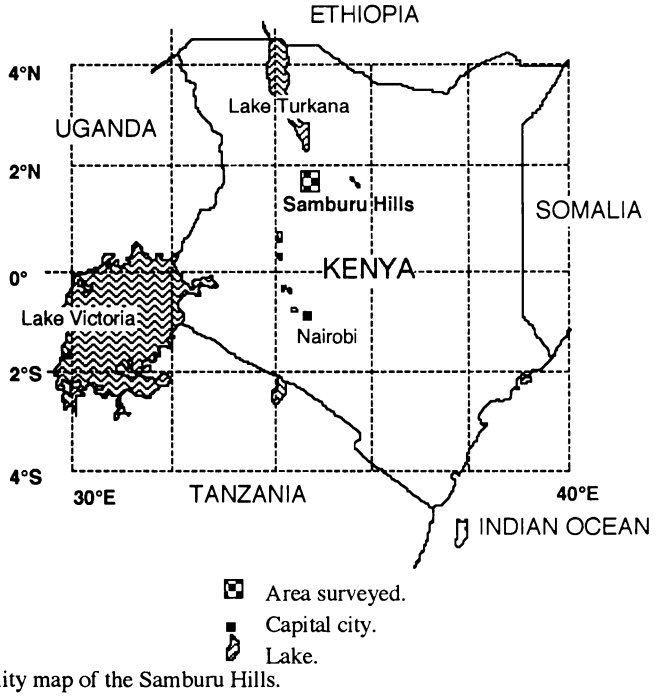


Fig. 1. Locality map of the Samburu Hills.

The Neogene sediments and volcanics in the Samburu Hills consist of the Nachola, Aka Aiteputh, Namurungule, Nanyangaten, Kongia, Nagbarat and Tirr Tirr Formations (Fig. 2).

The Namurungule Formation yields a large amount of diversified vertebrates which appear to be of late Miocene in age thus belong to an assemblage heretofore unknown (Nakaya et al., 1984). Itaya & Sawada (in press) determined by K-Ar dating method the age of the Kongia and Nanyangaten Formations (5.7-7.3 Ma) clinounconformably overlying the Namurungule Formation and the Aka Aiteputh Formation (10-15 Ma) which underlies the Namurungule Formation. Consequently, the Namurungule Formation has been dated approximately as 8 to 10 Ma. This age agrees with the discovered mammalian assemblage of the Namurungule Formation (Nakaya et al., in press). Five paleomagnetic-zones were identified in the Samburu Hills. The Aka Aiteputh Formation is correlated to paleomagnetic-zone V in the period between 9.78 Ma and 10.3 Ma (Nakajima & Torii, in press).

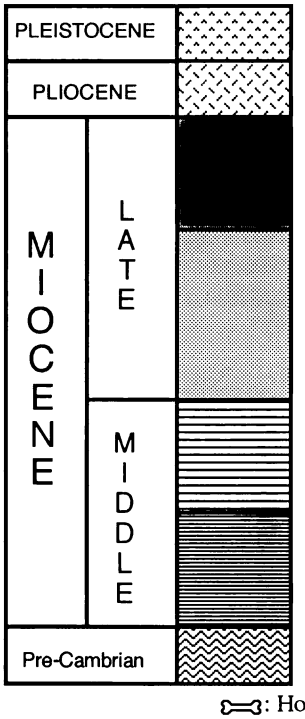


Fig. 2. Geology and geochronology of the Samburu Hills.

II. Excavation of the Namurungule Formation

1. 1982 Excavation

Osaka University expedition team collected fossil remains on the surface of the Namurungule Formation of the Samburu Hills at random in 1982 field season. We excavated at the SH-22 of the locality of *"Samburu Large Hominoid"* in detail. Fossil numbers at each locality in the Namurungule Formation and number of taxa from the Namurungule Formation are shown in the following figures (Fig. 3, 4).

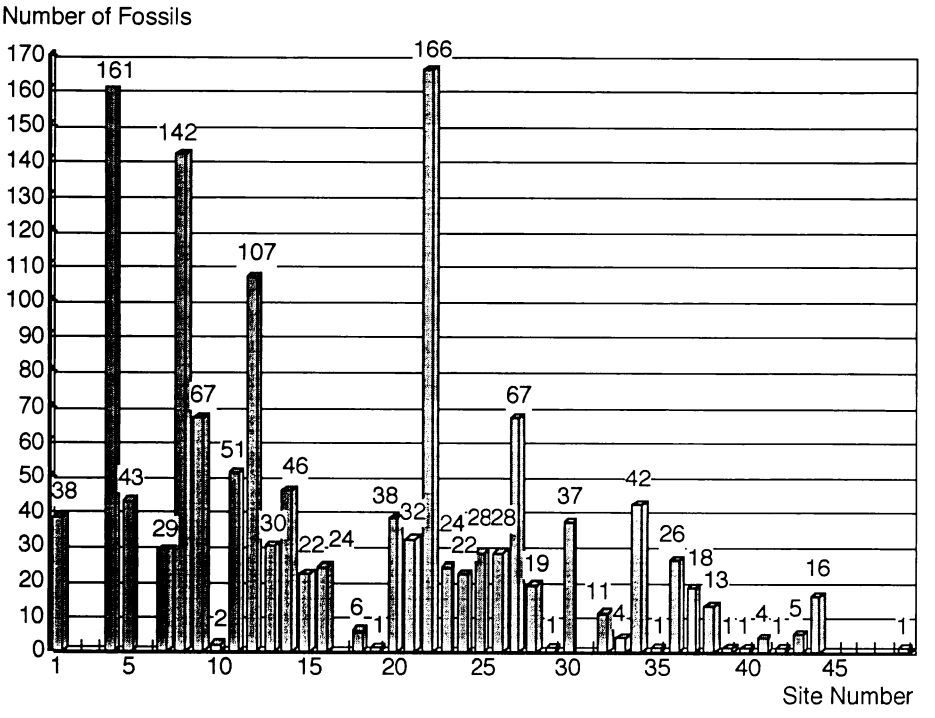


Fig. 3. Number of vertebrate fossils from each localities in the Samburu Hills.

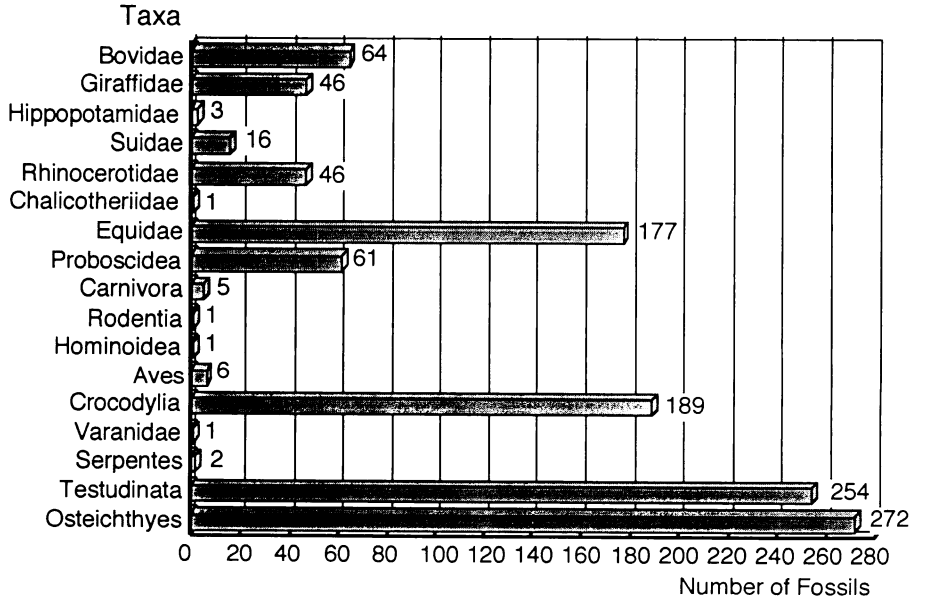


Fig. 4. Number of vertebrate taxa from the Namurungule Formation at 1982.

2. 1984 Excavation

In 1984 field season, Osaka University expedition team also collected fossil remains which were already surveyed in 1982 and newly discovered in 1984 randomly from the site surface of Samburu Hills and excavated locality SH-22 and some mammalian localities in detail.

3. 1986 Excavation

Osaka University expedition team also collected fossil remains which were already surveyed in 1984 randomly from the site surface of Samburu Hills in 1986 field season, and excavated locality SH-22 in detail. Fossil vertebrate localities show Figure 5.

4. 1988 Excavation

Osaka University expedition team also collected fossil remains which were already surveyed in 1986 randomly from the site surface of Samburu Hills in 1988 field season, and excavated locality SH-22 in detail by electric drilling machine.

5. Localities of Vertebrate Fossils and Stratigraphy of the Namurungule Formation

The Namurungule Formation consists of the Lower Member, Mud Flow, Upper Member in ascending order. The Lower Member consists of conglomerate, sand-stone, thin mud flow deposits, pyroclastics, alternating beds of sandstone and mudstone predominantly in sandstone. The Mud Flow consists of reddish mud flow deposits 10-20 meter thick. The Upper Member consists of alternating beds of sandstone and mudstone predominantly in mudstone.

The Lower Member of Namurungule Formation yields the following vertebrate localities.

Locality SH-1, 7-9, 20-24, 26, 27, 30, 34, 40, 43, 44, 49-58, 61-64.

In the Upper Member of Namurungule Formation, we found the following vertebrate localities.

Locality SH-4, 5, 10-16, 18, 19, 25, 28, 29, 32, 33, 35-39, 41, 42, 60 (Fig. 5).

6. Taphonomy of Vertebrate Fossils in Situ

Almost all fossils were collected from the surface of the Namurungule Formation in the Samburu Hills. Some mammalian remains were excavated *in situ* of the Namurungule Formation in 1984. Almost all fossils were destroyed and weathered on the end position of skeleton because of the rolling before embedded in the deposits. For example, the skull of *Hipparion* from locality SH-53 was missing the incisive and occipital part. The mandible of *Deinotherium* from locality SH-54 was also missing the incisive, ventral border and ramus part. These remains were discovered in the overturned position in the sediments. The surface of some astragali of Giraffidae seems to be dissolved in acid solution. The surface shape of these astragali are different from that of rolled remains in the river. The edge of articular surface of these astragali is sharper than the original shape of articular part. The edge of articular surface of rolled remains in the river is rounded. These astragali remains may be stomach stones of crocodiles (Pickford, pers. comm.).

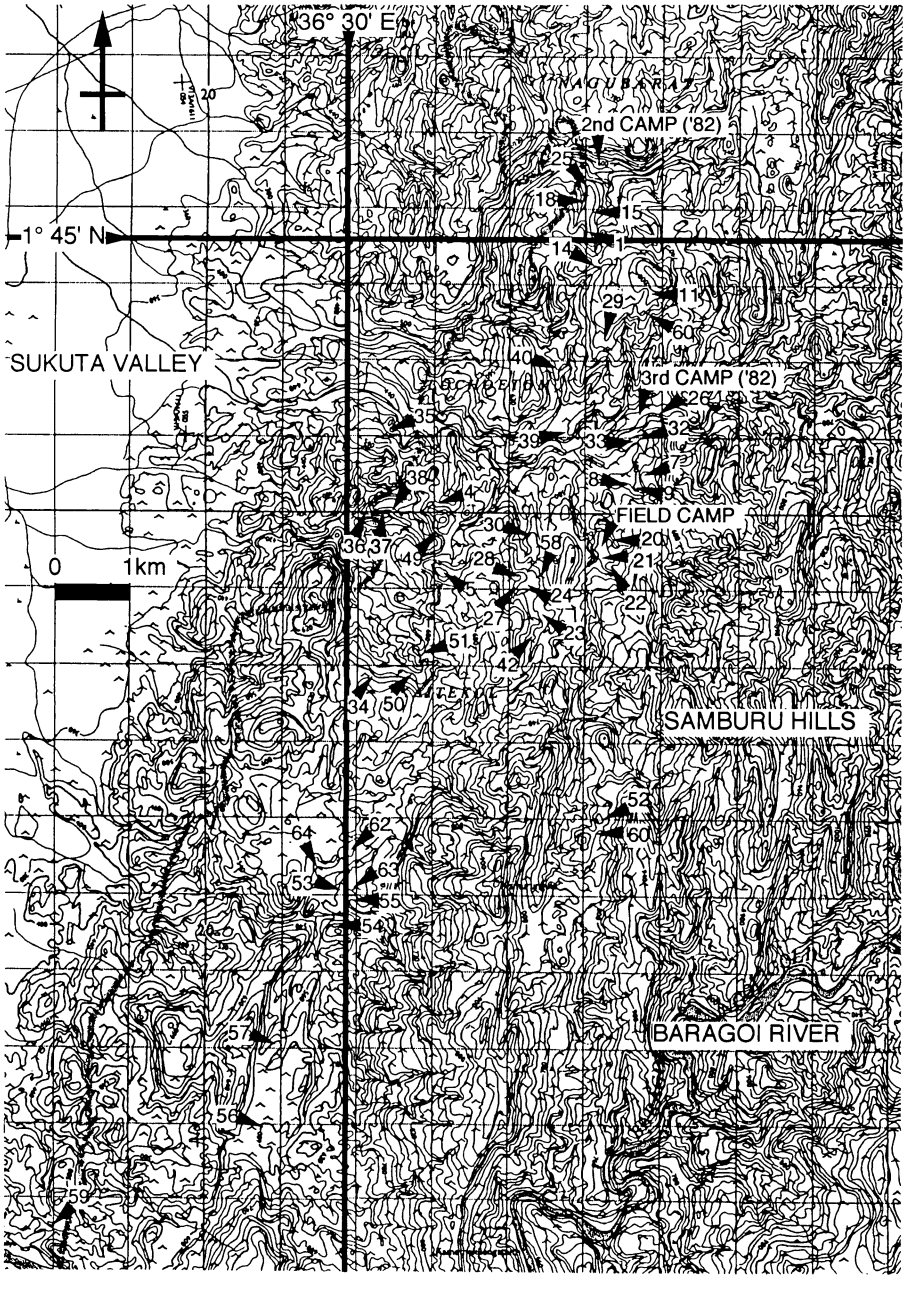


Fig. 5. Localities of vertebrate fossils in the Samburu Hills.
Topographic maps are based on sheets "Lobar" (65/1), "Kangaurak" (65/3), "Sukuta Valley" (64/2) and "Lomaro" (64/4) of series Y 731 (D.O.S. 423) 1:50,000 Topographic map published by D.O.S. for the Kenya Government (Survey of Kenya), 1982. Each grid is 1 km square.

7. Paleoenvironments of the Namurungule Formation

Sedimentological characteristics of the Namurungule Formation indicate lacustrine and fluvial environments (Makinouchi et al., 1984; Sawada et al., in press). Taphonomical evidence also assists such environments of the Namurungule Formation. The most abundant remains are fresh water fish. Crocodilian and chelonian fossils are also rich in the Namurungule Formation (Nakaya et al., 1984, in press; Pickford et al., 1984).

THE NAMURUNGULE FAUNA

I. Significance of the Namurungule Fauna

Three formations, the Aka Aiteputh, Namurungule, Kongia Formation, yield Neogene vertebrate fossils in the Samburu Hills. In this chapter, fossil assemblage and sedimentological facies of these formations are described.

1. The Aka Aiteputh Fauna

This fauna is characterized by yielding abundant fossil primate remains (Pickford & Kuga, in press). The sedimentological facies indicates lacustrine environments, because the clastic sediments of the Aka Aiteputh Formation is mainly composed of fine sandstone and silt, and these fine sediments are partially silicified (Sawada et al., in press).

Mollusca
Gastropoda
  Ampullariidae
    Lanistes carinatus
  Pomatiasidae
    Tropidophora (Ligatella) miocenica
Bivalvia
  Mutelidae
    Etheria elliptica
Pisces
Reptilia
Crocodylia
  Crocodylidae
    gen. et sp. indet.
Testudines
  Trionychidae
    gen. et sp. indet.
  Pelomedusidae
    gen. et sp. indet.
Squamata
  Serpentes
    gen. et sp. indet.
Aves

gen. et sp. indet.
Mammalia
Primates
Cercophithecoidae
Nyanzapithecus sp.
Victoriapithecus sp.
Hominoidea
Proconsul sp.
Kenyapithecus cf. *africanus*
Rodentia
Paraphiomys cf. *pigotti*
Proboscidea
Gomphotherium sp.
Prodeinotherium sp.
Perissodactyla
Rhinocerotidae gen. et sp. indet.
Artiodactyla
Anthracotheriidae
Hyoboops sp.
Hemimeryx sp.
Sanitheriidae
Diamantohyus africanus
Suidae
Libycochoerus sp. nov.
Climacoceridae
Climacoceras gentryi
Tragulidae
Dorcatherium cf. *pigotti*
Dorcatherium chappusi
? Giraffidae ?
Walangania africanus
Bovidae gen. et sp. indet

2. The Namurungule Fauna

The number of fossils of each taxon from the Namurungule Formation in 1982 excavation (Nakaya et al., 1984) is shown in Figure 4. for analyzing paleoenvironments of the fauna. Aqueous taxa (Pisces: Osteichthyes, Testudinata and Crocodylia) have numerous remains. This result supports the sedimentological and taphonomical evidence that the Namurungule Formation is lacustrine and/or fluvial in origin because of the predominant of the alternating bed and trough-type cross lamination of the coarse sediments (Sawada et al., in press). The appearance of numerous equids and bovids from the Namurungule Formation indicates the open country and/or woodland environments of the background (Nakaya et al., in press; Nakaya, 1987, 1989, 1993). Very large number of equid, giraffid and bovid remains shows that these taxa were social behavior animal. Very small number of chalicothere remains shows that this taxa was solitary animal on the view of paleoecological point.

Mollusca
Gastropoda
Limicolaria aff. *martensiana*
Trochonania (Bloyetia) aff. *nyroensis*
Pisces
Reptilia
Crocodylia
Crocodylidae
gen. et sp. indet.
Testudines
Trionychidae
gen. et sp. indet.
Pelomedusidae
gen. et sp. indet.
Squamata
Sauria
Varanidae
gen. et sp. indet.
Serpentes
gen. et sp. indet.
Aves
gen. et sp. indet.
Mammalia
Primates
Hominoidea
Genus and species nov.
Rodentia
Thryonomyidae
Paraphiomys sp.
Paraulacodus sp.
Hystricidae
Carnivora
Hyaenidae spp.
Felidae
Machairodontinae
gen. et sp. indet.
Proboscidea
Gomphotheriidae
Tetralophodon sp. nov.
Deinotheriidae
Deinotherium cf. *bozasi*
Perissodactyla
Equidae
Hipparion africanum
Chalicotheriidae
gen. et sp. indet.
Rhinocerotidae

Paradiceros mukirii
Chilotheridium pattersoni
Kenyatherium bishopi
Iranotheriinae sp. nov.
Artiodactyla
Suidae
Nyanzachoerus tulotos (small form)
Nyanzachoerus kanamensis (large form)
Hippopotamidae
Kenyapotamus coryndoni
Giraffidae
Palaeotragus sp. nov.
Samotherium ? sp.
Bovidae
Pachytragus laticeps
Miotragocerus sp.
Ouzocerus ? sp.
Gazella spp.

3. The Kongia Fauna

Of this fauna, mammalian remains have not yet been investigated in detail. Studies are confined to geochronological aspects. This Formation indicates lacustrine and/or fluvial in origin because of the predominance of fine sandstone and silt, and the alternation of sandstone and silt (Sawada et al., in press). The following taxa indicate riverine habitats.

Mollusca
Gastropoda
Burtoa nilotica
Chlamydarion aff. *haans*
Limicolaria aff. *martensiana*
Trochonania (Bloyetia) aff. *nyroensis*
Tropidophora (Ligatella) aff. *anceps*
Cleopatra aff. *africana*
Mellanoides tuberculata
Bivalvia
Mutela sp.
Insecta
Pisces
Reptilia
Squamata
Sauria
Varanidae
gen. et sp. indet.
Artiodactyla
Hippopotamidae
Hippopotamus sp.

II. Phylogeny and Paleobiogeography of the Namurungule Fauna

In this chapter, habitat of each taxa from the Namurungule Fauna, first appearance of the world and Sub-Saharan Africa, and distribution in the late Miocene are described (Nakaya et al., 1984, in press; Nakaya, 1987, 1989, 1993).

1. Primates

Hominoidea gen. et sp. nov.

This taxon, so called *"Samburu Large Hominoid"*, is represented by the left Maxilla with cheek teeth from the Lower Member of Namurungule Formation. Samburu Hominoid is very unique and it is probable that this taxon is a common ancestor of australopithecine of the Hominidae and African ape *(Pan* and *Gorilla)* of the Hominoidea (Ishida et al., 1984, Groves, 1989). First appearance of Hominoidea was *Aegyptopithecus* from late Oligocene, Fayum, Egypt (Szalay & Delson, 1979). First appearance of this superfamily from Sub-Saharan Africa was *Proconsul, Limnopithecus* from early Miocene Karungu (Simons et al., 1978). Distribution of this taxon in the late Miocene was only *"Samburu Hominoid"* from this fauna in Sub-Saharan Africa. It has been made clear that ramapithecine from late Miocene Eurasia and *Pongo* (Orang-Utan) shared same clade (Martin, 1986). Because of this point of view, it has to be stressed that new hominoid fossil from the Namurungule Formation fills in the missing link of human evolution.

2. Rodentia

Thryonomyidae

Paraphiomys sp.

One left mandible fragment with cheek teeth of *Paraphiomys* sp. from the Lower Member of Namurungule Formation occurs (Kawamura & Nakaya, 1984). First appearance of genus *Paraphiomys* was *P. simonsi* from Oligocene (25 Ma) of Fayum (Wood, 1968). First appearance of this taxon from Sub-Saharan Africa was *Paraphiomys pigotti* and *P. stromeri* from early Miocene (Lavocat, 1973). Only *P. occidentalis* is known from the late Miocene deposit of Morocco (Lavocat, 1961). Only one genus *Paraphiomys* is known.

Paraulacodus sp.

Only one isolated right upper incisor of *Paraulacodus* sp. is known from the Lower Member of Namurungule Formation (Kawamura & Nakaya, in press). First appearance of genus *Paraulacodus* is shown by *P. indicus* from the Chinji Formation of Pakistan (Flyn et al., 1983). First appearance of this taxon from Sub-Saharan Africa was represented by *Paraulacodus johanesi* from the late Miocene Chorora Formation of Ethiopia (Jacobs et al., 1980). Distribution of this genus in the late Miocene is represented by the Chorora and Namurungule Fauna only.

3. Carnivora

Hyaenidae spp.

Hyaenidae from the Upper and Lower Member of Namurungule Formation consists of three taxa, based on tooth size. These hyaenids are represented by the isolated lower cheek teeth or fragments of mandible, therefore, genus and species cannot be determined precisely (Nakaya et al., 1984, in press). First appearance of Hyaenidae is known from Orleanian (MN 4) in Europe (Savage & Russell, 1983). First appearance of this taxon from Sub-Saharan Africa is shown by the early Miocene of Fort Ternan (Savage, 1978). Distribution of this family in the late Miocene is known from East and North Africa, Southwest and Central Europe, Sub-Paratethys, Siwaliks and East Asia (Hendey, 1974; Savage, 1978; Savage & Russell, 1983; Schmidt-Kittler, 1976, 1987).

Felidae

Machairodontinae gen. et sp. indet.

Only one isolated lower canine of Machairodontinae is found from the Lower Member of Namurungule Formation (Nakaya et al., in press). First appearance of this taxon is known from Vallesian (MN 9) in Europe (Savage & Russell, 1983). First appearance of this subfamily from Sub-Saharan Africa is represented by this Namurungule occurrence. Distribution of this subfamily in the late Miocene is known from East and North Africa, Southwest and Central Europe, Sub-Paratethys, Siwaliks and East Asia (Savage & Russell, 1983).

4. Proboscidea

Gomphotheriidae

Tetralophodon sp. nov.

One Proboscidean skull was excavated from the Lower Member of Namurungule Formation on 1984, and it is now under preparation in the National Museums of Kenya. This skull has typical cheek teeth of the genus *Tetralophodon*, because the intermediate molar with four lophs is characterized by tetralophodont cusp pattern. In comparing with the angle of the basicranium of *Tetralophodon* of Eurasia and of the Namurungule Fauna (Nakaya et al., in press), it is known that typical European *Tetralophodon* (Tobien, 1973a, 1973b, 1978) has a low angle of the basicranium, however, the Namurungule specimen has a high angle (Fig. 6). *Paratetralophodon* from the Siwaliks has also high angle of basicranium (Tassy, 1983). First appearance of genus *Tetralophodon* is known as *T. longirostris* from the Vallesian in Europe (Tobien, 1978). First appearance of this taxon from Sub-Saharan Africa is known as a Tetralophodont form gen. et sp. indet. from middle Miocene Ngorora Formation (member D) (Tassy, 1986). Distribution of this genus in the late Miocene is known from East and North Africa, Southwest and Central Europe, Sub-Paratethys, Siwaliks and East Asia (Tobien, 1978; Savage & Russell, 1983).

Deinotheriidae

Deinotherium cf. *bozasi*

A mandible and cheek teeth of *Deinotherium* are found from the Upper and Lower Member of the Namurungule Formation (Nakaya et al., 1984, in press). First appearance

of genus *Deinotherium* is known from the early Miocene of Eurasia. First appearance of Deinotheriidae from Sub-Saharan Africa is known as *Prodeinotherium hobleyi* from the early Miocene of Bukwa and Karungu and *Deinotherium* cf. *bozasi* from the late Miocene of Nakali and Namurungule Fauna. *D. bozasi* is distinguished from *P. hobleyi* in size and the morphology of skull and upper cheek teeth (Harris, 1973, 1975, 1976, 1978). *D. bozasi* is known from the late Miocene of East Africa and the Pliocene to Pleistocene of Sub-Saharan Africa (from Ethiopia to Mozambique) (Harris, 1977; Nakaya et al., in press). Distribution of this genus in the late Miocene is known from East and North Africa, Southwest and Central Europe, Sub-Paratethys, Siwaliks and East Asia (Osborn, 1936; Savage & Russell, 1983).

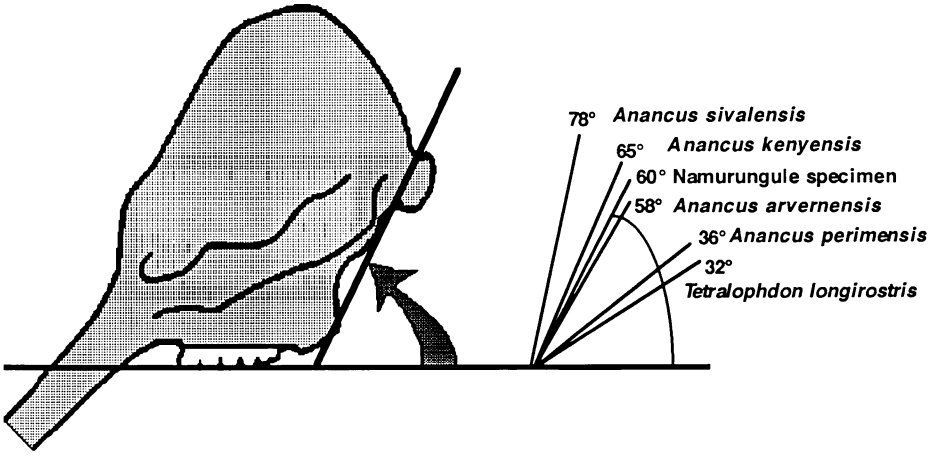


Fig. 6. Angle of tetralophodont basicranium (Modified after Tassy, 1983).
left; measuring method of the angle of basicranium.
right; angle of tetralophodont (*Tetralophodon* and *Anancus* group).

5. Perissodactyla

Equidae

Hipparion africanum

The skull of hipparionine (Equidae) from the Upper and Lower Member of Namurungule Formation will be described and discussed by the author and Watabe, on its phylogenetic relationships with other African and Eurasian forms (Nakaya & Watabe, 1990). On the basis of the cranial morphology, especially preorbital fossa (POF) and dentition, this skull is similar to *Hipparion africanum* (Arambourg, 1959) from Bou Hanifia of North Africa of Vallesian age, and the proportions of slender limb bones from the Namurungule Formation is also comparable with those of the same *Hipparion*. Furthermore, this skull shows similarities to *Cormohipparion perimense* (Bernor & Hussain, 1985) from the Siwaliks on the basis of the morphology of antero-dorsally located POF. The age of *H. africanum* is older than the Namurungule Formation, and the age of the Dhok Pathan Formation of the Siwalik Hills yielding *C. perimense* is later than

that of the Namurungule Formation (Nakaya et al., in press). *Hipparion* suggests an open country habitat. First appearance of *H. africanum* is known from Vallesian of North Africa, *H. primigenium* was Vallesian Europe (Savage & Russell, 1983) and first appearance of *C. perimense* was in Siwaliks (Bernor & Hussain, 1985). First appearance of *H. africanum* from Sub-Saharan Africa was known from the Namurungule Formation. So called *Hipparion* found from Ngorora Formation first in Sub-Saharan Africa (Hooijer, 1975; 1976, Hooijer & Maglio, 1973, 1974; Bishop & Pickford, 1975; Pickford, 1978a). Figure 7 shows distribution of this genus in the late Miocene East and North Africa, Southwest and Central Europe, Sub-Paratethys, Siwaliks, East and Central Asia and North America (Forstén, 1968, 1972, 1978, 1979, 1980a, 1980b, 1981, 1983, 1984; Eisenmann, 1977, 1979, 1982; Bernor & Hussain, 1985; MacFadden & Baker, 1979; MacFadden & Skinner, 1981; Singer & Boné, 1966; Woodburne & Bernor, 1980).

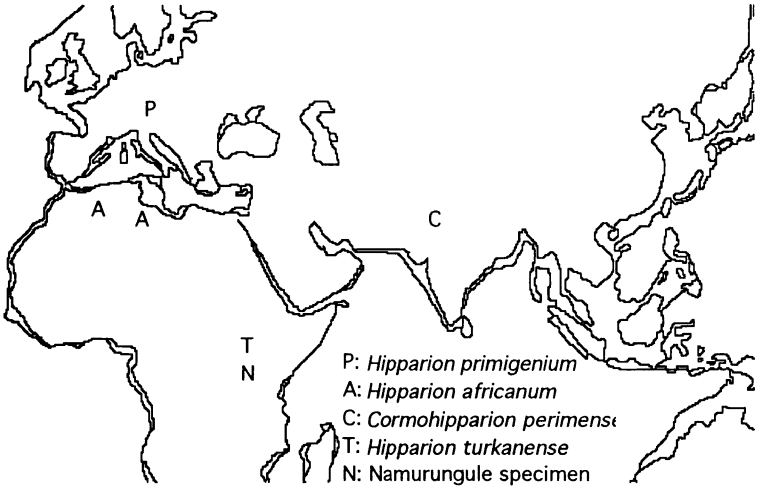


Fig. 7. Late Miocene fossil localities of large hipparionine from Africa and Eurasia.

Chalicotheriidae genus and species indeterminate

One basal phalange of the manus of Chalicotheriidae was collected from the Upper Member of Namurungule Formation (Nakaya et al., 1984). First appearance of this family is known from Sparnacisan (Eocene) of Southwest Europe (Savage & Russell, 1983). First appearance of this taxon from Sub-Saharan Africa is *Chalicotherium rusingense* from early Miocene of East Africa. *Ancylotherium hennigi* was distributed from the late Miocene to early Pleistocene of East and South Africa (Butler, 1978). Distribution of this family in the late Miocene is known from East and North Africa, Southwest and Central Europe, Sub-Paratethys, Siwaliks and East Asia (Savage & Russell, 1983).

Rhinocerotidae

Paradiceros mukirii

Cheek teeth of brachyodont Rhinocerotidae *Paradiceros mukirii* were found from the

Lower Member of Namurungule Formation (Nakaya et al., in press). First appearance of *P. mukirii* is known from the middle Miocene of Fort Ternan (Hooijer, 1968). This genus includes only one species; only *P. mukirii* occurs at Fort Ternan in Kenya. Distribution of this taxon in the late Miocene is known from this fauna only (Hooijer, 1966, 1968, 1971, 1972, 1973).

Chilotheridium pattersoni

Cheek teeth of hypsodont Rhinocerotidae being indicated to *Chilotheridium pattersoni* were found from the Lower Member of Namurungule Formation (Nakaya et al., in press). First appearance of *C. pattersoni* is known from the early Miocene (Hooijer, 1971). This taxon ranges from the early to late Miocene of East Africa. Distribution of this taxon in the late Miocene is known from East Africa only (Hooijer, 1966, 1968, 1971, 1972, 1973, 1978).

Kenyatherium bishopi

Some cheek teeth of *Kenyatherium bishopi* were found from the Lower Member of Namurungule Formation (Nakaya et al., in press). *K. bishopi* is from late Miocene of Nakali of particular interest among Rhinocerotidae characterized by a constricted protocone (Aguirre & Guérin, 1974). This taxon belongs to the subfamily Iranotheriinae. First appearance of this subfamily is known from the middle Miocene and it is represented by *Hispanotherium* from Iberian Peninsula (Crusafont-Pairo & de Villalta-Comella, 1947) and Turkey (Heissig, 1974), *Beliajevina* from Turkey (Heissig, 1974) and *Caementodon* from the Siwaliks (Heissig, 1972). Distribution of this subfamily in the late Miocene is represented by *Kenyatherium* from East Africa, *Iranotherium* from Iran (Mecquenem, 1908-1911) and *Sinotherium* from Northern China (Ringström, 1922, 1924, 1927) (Fig. 8).

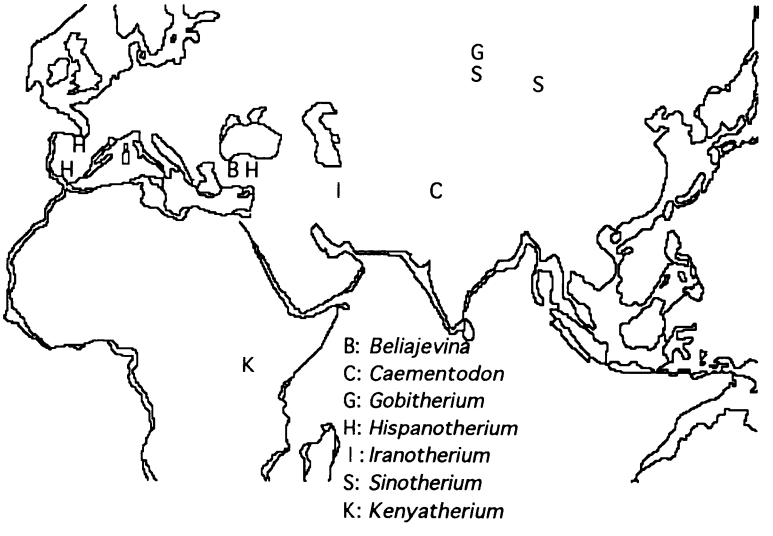


Fig. 8. Middle and late Miocene fossil localities of iranotheriinine from Africa and Eurasia.

Iranotheriinae sp. nov.

Some specimens of the rhinocerotid from the Lower Member of the Namurungule Formation are not identified with any Sub-Saharan rhinocerotids (Hamilton, 1973b; Hooijer, 1966, 1968, 1971, 1972, 1973). *Kenyatherium bishopi* is similar to these materials on the basis of the morphology of cheek teeth. However, the cheek teeth of this taxon are larger than those of *K. bishopi* (Nakaya et al., in press), therefore, it appears from the above that these materials represent a new taxon.

6. Artiodactyla

Suidae

Nyanzachoerus tulotos(small form)

Nyanzachoerus kanamensis(large form)

Two different species of *Nyanzachoerus* on the basis of the cheek teeth size, were found from the Upper and Lower Members of Namurungule Formation (Nakaya et al., in press). *Nyanzachoerus* suggests an open country habitat. First appearance of this genus is known from the late Miocene of Bou Hanifia (Algeria) (Arambourg, 1968). First appearance of this taxon from Sub-Saharan Africa is known from the Namurungule Formation. *Nyanzachoerus* was distributed in North and East Africa during the late Miocene (Arambourg, 1968; Bernor, 1986; Cooke & Ewer, 1972; Harris & White, 1979, White & Harris, 1977, Wilkinson, 1976).

Hippopotamidae

Kenyapotamus coryndoni

Complete mandible and the cheek teeth of *Kenyapotamus* are found newly from the Upper and Lower Members of Namurungule Formation. *Kenyapotamus* includes only two species, *K. coryndoni* and *K. ternani*. Habitat of *Kenyapotamus* suggests on riverine habitat. First appearance of genus *Kenyapotamus* is known as *K. ternani* from the middle Miocene of Fort Ternan and Maboko of Kenya. *K. coryndoni* is known from late Miocene Ngeringerowa (Pickford, 1983) and the Namurungule Fauna only.

Tragulidae

gen. et sp. indet.

A left talus of Tragulidae was found from the Upper Member of Namurungule Formation. Tragulidae suggests a forest habitat. First appearance of Tragulidae from Sub-Saharan Africa is known as *Dorcatherium chappuisi* from the early Miocene of Moruorot, Kenya (Whintworth, 1958). Distribution of this family in the late Miocene is known from Southwest and Central Europe, Sub-Paratethys, Siwaliks and East Asia (Savage & Russell, 1983).

Giraffidae

Palaeotragus sp. nov.

The giraffid's cheek teeth from the Upper and Lower Members of Namurungule Formation is similar to those of *Palaeotragus primaevus*, but the shape of hypocone of

upper molar of them is different from other species of Giraffidae in Africa (Nakaya et al., 1984, in press). *Palaeotragus* suggests a wooded open country habitat. First appearance of this genus is known as *P. primaevus* from the early Miocene of Moruorot, Kenya (Singer & Boné, 1960; Gentry, 1978a; Hamilton, 1973a, 1978). Distribution of this genus in the late Miocene is known as *P. germaini* from Lothagam, Kenya (Churcher, 1979) in East Africa.

Samotherium? sp.

Some limb bones of giraffid were obtained from the Upper and Lower Members of Namurungule Formation. They are larger than specimens of *Palaeotragus* (Nakaya et al., in press). These materials are identified as *Samotherium* ? sp. *Samotherium* suggests a wooded open country habitat. First appearance of *Samotherium* is known from the middle Miocene of Pasalar, Turkey (Bernor & Pavlakis, 1987). First appearance of this taxon in Sub-Saharan Africa is known as *Samotherium africanum* from the middle Miocene of Fort Ternan (Churcher, 1978). Distribution of this genus in the late Miocene is known to extend to East and North Africa, Southwest and Central Europe, Sub-Paratethys, Siwaliks and East Asia (Savage & Russell, 1983).

Bovidae

Pachytragus laticeps

Horn cores, compressed oval in section and curved uniformly, but gently backwards toward the tip, are discovered from the Lower Member of Namurungule Formation. They are identified as *Pachytragus laticeps* (Nakaya et al., 1984, in press and this work). This species was taxonomically revised to *Protoryx laticeps* by Solounias (1981). First appearance of *Pachytragus* and/or *Protoryx* is known from the late Miocene North Africa and Sub-Paratethys (Solounias, 1981; Savage & Russell, 1983). *Pachytragus* suggests an open country habitat. First appearance of this taxon from Sub-Saharan Africa confines to the Namurungule Formation. Distribution of this taxon in the late Miocene is *P. solignaci* from Beglia (Robinson, 1972) and the Namurungule Fauna in Africa. This genus group is widely known from Afro-Eurasia (East and North Africa, Southwest and Central Europe, Sub-Paratethys, Siwaliks and East Asia) during the late Miocene (Savage & Russell, 1983).

Miotragocerus sp.

A horn core, curved and spiral with an anterior keel, from the Lower Member of Namurungule Formation is identified as *Miotragocerus* (Nakaya et al., 1984). First appearance of this genus was Astaracian (Savage & Russell, 1983). *Miotragocerus* suggests an open country habitat. First appearance of this taxon from Sub-Saharan Africa is known from the Namurungule Fauna. This genus is known from Afro-Eurasia widely (East and North Africa, Southwest and Central Europe, Sub-Paratethys, Siwaliks and East Asia) during the late Miocene (Savage & Russell, 1983).

Table 1. Faunal resemblance of the Namurungule Fauna and Eurasian faunas.

Mammalia	
Primates	
Hominoidea	
Genus and species nov.	A
Rodentia	
Thryonomyidae	
Paraphiomys sp.	A
Paraulacodus sp.	S
Carnivora	
Hyaenidae spp.	E
Felidae	
Machairodontinae	
gen. et sp. indet.	E
Proboscidea	
Gomphotheriidae	
Tetralophodon sp. nov.	E
Deinotheriidae	
Deinotherium cf. *bozasi*	E
Perissodactyla	
Equidae	
Hipparion africanum	N
Chalicotheriidae	
gen. et sp. indet.	E
Rhinocerotidae	
Paradiceros mukirii	A
Chilotheridium pattersoni	A
Kenyatherium bishopi	A
Iranotheriinae sp. nov.	A
Artiodactyla	
Suidae	
Nyanzachoerus tulotos (small form)	N
Nyanzachoerus kanamensis (large form)	N
Hippopotamidae	
Kenyapotamus coryndoni	A
Giraffidae	
Palaeotragus sp. nov.	E
Samotherium ? sp.	E
Bovidae	
Pachytragus laticeps	P
Miotragocerus sp.	E
Ouzocerus ? sp.	N,P
Gazella spp.	E

Notes: A: unique Sub-Saharan taxa; N: common with North Africa taxa; P: common with Sub-Paratethys taxa; S: common with Siwalik taxa; E: common with Eurasia taxa.

Ouzocerus? sp.

Skull and horn cores that are nearly circular in section with a sharp posterior keel, from the Upper and Lower Members of Namurungule Formation are identified as *Palaeoreas* sp. (Nakaya et al., 1984). However *Ouzocerus* described newly is more similar to this specimen (this work). This genus includes only one species, *O. gracilis*, and is known from Vallesian of northern Greece for the first time (Bouvrain & Bonis, 1986) and the late Miocene Beglia Formation of Tunisia (Thomas, pers. comm.). First appearance of this taxon from Sub-Saharan Africa is known from the Namurungule Formation. Distribution of this taxon is known from East and North Africa and Sub-Paratethys during the late Miocene.

Gazella sp.

Some horn cores of *Gazella* were discovered from the Upper and Lower Member of Namurungule Formation (Nakaya et al., 1984, in press). This genus includes many species. *Gazella* suggests an open country habitat. First appearance of this genus is known from the early Miocene of Gebel Zelten, North Africa (Hamilton, 1973a). First appearance of this taxon from Sub-Saharan Africa is known as *Gazella* sp. from the middle Miocene of Fort Ternan (Gentry, 1978b). This genus is known from Afro-Eurasia widely (East and North Africa, Southwest and Central Europe, Sub-Paratethys, Siwaliks and East Asia) during the late Miocene (Gentry, 1966, 1967, 1970, 1971, 1978a, b, 1980; Gentry & Gentry, 1978; Savage & Russell, 1983).

Resemblance of the Namurungule Fauna and other Eurasian faunas is shown in the Table 1.

III. Correlation and Resemblance of Neogene Mammalian Faunas of Sub-Saharan Africa and Eurasia

1. Late Miocene faunas of North Africa and Eurasia

In this chapter, the author describes typical late Miocene (Astaracian, Vallesian and Turolian) faunas of North Africa and Eurasia for the sake of making comparison with mammalian faunas of Sub-Saharan Africa.

(1) Eurasia (Western)

West Eurasian Neogene mammals have been studied since the eighteenth century. Ages of the Eurasian Neogene mammal and fossil assemblage zones in Southwestern Europe, Greece and Iran were revised by Savage & Russell (1983). The following five mammalian ages and 13 mammalian zones during the Miocene and two ages and four zones during the Pliocene were established respectively by them.

Miocene
- Agenian (20-25 Ma)
  - MN 1
  - MN 2a
  - MN 2b

Orleanian (15-20 Ma)
MN 3a
MN 3b
MN 4a
MN 4b
MN 5
Astaracian (12-15 Ma)
MN 6
MN 7
MN 8
Vallesian (10-12 Ma)
MN 9
MN 10
Turolian (5-10 Ma)
MN 11
MN 12
MN 13
Pliocene
Ruscinian (-5 Ma)
MN 14
MN 15
Villafranchian (2- Ma)
MN 16a
MN 16b
MN 17

(2) Siwaliks

Falconer & Cautley (1846-1849) started the study of geology and paleontology of the Siwalik Hills. Pilgrim (1913) divided mammalian faunas and strata of the Siwaliks into seven stages and correlated them to the standard Neogene stages in Europe. Colbert (1935) revised Pilgrim's correlation and compared it to equivalents in Europe and America. In 1960's, *Ramapithecus* from the Siwaliks was reevaluated as a human ancestor (Simons, 1961). During 1950-1970s, many teams (Dehm et al., 1958; Pilbeam et al., 1977) excavated again at the Siwalik Hills. Research on faunal assemblage (Pilbeam et al., 1977; Moonen et al., 1978) and phylogenetic studies of each taxa have been published (Dehm et al., 1958, 1963; Hussain, 1971; Heissig, 1972; Jacobs, 1978; Tassy, 1983; Pickford, 1988), and geochronological data of strata of this area were obtained. The results of stratigraphic study of Siwaliks are shown in the following table (Pilbeam et al., 1977; Opdyke et al., 1979).

Miocene
Kamlial (before 13 Ma; Pilbeam et al., 1977)
Chinji (11-13 Ma; Pilbeam et al. 1977)
Nagri (9-10 Ma; Pilbeam et al., 1977)
Dhok Pathan (6.5-9 Ma; Pilbeam et al., 1977)
Pliocene
Tatrot (before 2.47 Ma; Opdyke et al. 1979)

Pinjor (after 2.47 Ma; Opdyke et al. 1979)

(3) China

Many researchers studied Chinese Neogene terrestrial mammals and furthermore, Quaternary mammals with *Sinanthropus pekinensis* (*Homo erectus*) until 1940's (Andersson, 1923; Bohlin, 1937; Koken 1885; Ringström, 1922, 1924, 1927; Schlosser, 1924; Teilhard de Chardin, 1926; Teilhard de Chardin & Young; 1930, 1931; Zdansky, 1930). Researchers of the Institute of Vertebrate Paleontology and Paleoanthropology (Beijing) began again to study fossil vertebrates from China since 1948. Cenozoic terrestrial stratigraphy in China was revised by Yen et al. eds., (1984). Established Neogene terrestrial zones of mammals in China are as follows.

Early Miocene
- Xiejean (19-24 Ma)

Middle Miocene
- Shanwangian (15-19 Ma)
- Tungurian (12-15 Ma)

Late Miocene
- Bahean (9-12 Ma)
- Baodean (5-9 Ma)

Pliocene
- Gaozhuangian
- Youhean
- Nihewanian

The following typical faunas from Astaracian to Turolian Sub-Saharan Africa and Eurasia treated in the next chapter have been correlated as shown in Table 2.

Table 2. Astaracian to Turolian typical mammalian localities from Sub-Saharan Africa and Eurasia.

MIOCENE		Ma	East Africa	North Africa	West & Central Europe	Sub-Paratethys	Siwaliks	North China
LATE	Turolian	5	Lukeino Mpesida	Sahabi				Yushe I
			Namurungule				Dhok Pathan	Baode
	Vallesian	10	Ngeringerowa Nakali Ngorora E		Mt. Lebéron	Samos Maragheh Pikermi	Nagri	
MIDDLE	Astaracian	12	Ngorora	Bou Hanifia				
			Aka Aiteputh				Chinji	

2. North Africa

Many localities of mammalian fauna are known from the late Miocene of North Africa. The following mammalian faunas are represented as Vallesian faunas (Beglia and Bou Hanifia) and Turolian fauna (Sahabi).

(1) Beglia (Tunisia)

This fauna is correlated to Vallesian fauna (MN 9) of North Africa. Some bovid taxa of this fauna are similar with those of the Namurungule Fauna. Faunal list of the Beglia Formation is as follows (Robinson, 1972; Robinson & Black, 1969; Thomas, pers. comm.).

Mammalia
Rodentia
Africanomys sp.
Testouromys sp.
Mellalomys atlasi
Creodonta
Hyaenodontidae gen. et sp. indet.
Carnivora
Mustelidae gen. et sp. indet.
Hyaenidae
Ictitherium sp.
Felidae
Machairodus sp.
Canidae
Afrocyon sp.
Sirenia
gen. et sp. indet
Artiodactyla
Bovidae
Pachytragus solignaci
Ouzocerus sp.

(2) Bou Hanifia, Oued-el-Hammam (Algeria)

This fauna is a typical Vallesian fauna (MN 9) in North Africa. Faunal list of the Bou Hanifia Fauna is as follows (Arambourg, 1959).

Aves
Struthio sp.
Mammalia
Primates
Cercopithecidae
Macaca flandrini
Rodentia
Hystricidae
Hystrix sp.
Carnivora
Hyaenidae

Hyaena algeriensis
Tubulidentata
Orycteropus mauritanicus
Proboscidea
gen. et sp. indet.
Perissodactyla
Equidae
Hipparion africanum
Rhinocerotidae
Dicerorhinus primaevus
Artiodactyla
Giraffidae
Palaeotragus germaini
Samotherium sp.
Bovidae
Damalavus boroccoi
Gazella praegaudryi
Tragocerus sp.
Cephalophus sp.

(3) Sahabi (Libya)

This fauna is a typical Turolian fauna in North Africa. Richness of equid and bovid taxa indicates open-country fauna. Faunal list of the Sahabi Fauna is as follows (Boaz et al. eds., 1987).

Insectivora
Soricidae
Crocidurinae gen. et sp. indet.
Primates
Hominoidea gen. et sp. indet.
Cercopithecidae
cf. *Libypithecus* sp.
Macaca sp.
Rodentia
Sciuridae
cf. *Atlantoxerus getulus*
Ctenodactylidae
Sayimys sp.
Cricetidae
aff. *Myocricetodon cherifensis*
Protatera yardangi
Muridae
Progonomys sp.
Cetacea
Delphinidae
cf. *Lagenorhynchus* sp.
Platanistidae gen. et sp. indet.

Carnivora
- Ursidae
  - *Indarctos atticus*
  - *Agriotherium* cf. *africanum*
- Viverridae
  - *Viverra* sp.
- Hyaenidae
  - *Percrocuta eximia*
  - *Percrocuta senyueki*
  - *Hyaenictitherium* sp.
  - *Euryboas* sp.
- Felidae
  - *Machairodus* sp.
  - sp. A
  - sp. B
  - sp. C
- Phocidae
  - aff. Monachinae gen. et sp. indet.

Proboscidea
- Gomphotheriidae
  - *Amebelodon cyrenaicus*
- Elephantidae
  - *Stegotetrabelodon lybicus*

Sirenia
- Dugongidae
  - *Metaxytherium serresii*

Perissodactyla
- Equidae
  - "*Hipparion*" cf. *africanum*
  - "*Hipparion*" cf. *sitifense*
- Rhinocerotidae
  - *Diceros neumayri*

Artiodactyla
- Suidae
  - *Nyanzachoerus* cf. *devauxi*
  - *Nyanzachoerus syrticus*
  - *Nyanzachoerus kanamensis*
- Anthracotheriidae
  - *Merycopotamus petrocchii*
- Hippopotamidae
  - *Hexaprotodon sahabiensis*
- Giraffidae
  - *Samotherium* sp.
- Bovidae
  - *Leptobos syrticus*
  - *Miotragocerus cyrenaicus*
  - *Redunca* aff. *darti*

?Hippotragus sp.
cf. *Damalacra* sp.
Raphicerus sp.
Gazella sp.
Prostrepsiceros (Prostrepsiceros) libycus

3. Southwestern and Central Europe

Many localities of mammalian fauna are known from the late Miocene in Southwestern and Central Europe. The following mammalian faunas are represented as Vallesian fauna (Eppelsheim) and Turolian faunas (Dorn-Dürkheim and Mt. Lebéron).

(1) Eppelsheim (West Germany)

This fauna is correlated with Vallesian (MN 9). Faunal list of the Eppelsheim Fauna is as follows (Gabuniya, 1959; Klipsten & Kaup, 1836; Wenz, 1921, 1931).

Mammalia
Primates
Pliohylobates eppelsheimensis
Rodentia
Gliridae
Steneofiber jägeri
Carnivora
Ursidae
Simocyon diaphorus
Hyaenidae
Ictitherium robustum
Felidae
Pontosmilus ogygius
Machairodus cultridens
Proboscidea
Mastodon (=*Gomphotherium*) *angustidens*
Mastodon (=*Gomphotherium*) *angustidens* var. *subtapiroidea*
Mastodon gigantorostris
Mastodon longirostris var. *dubius*
Mastodon longirostris var. *grandis*
Deinotheriidae
Deinotherium giganteus
Perissodactyla
Equidae
Anchitheirum sp.
Hipparion primigenium
Chalicotheriidae
Chalicotherium goldfussi
Rhinocerotidae
Aceratheriinae Tribe Aceratherini
Aceratherium incisivum
Brachypotherium goldfussi

Rhinocerotinae Tribe Rhinocerotini
Dicerorhinus schleiermacheri
Dicerorhinus belvederensis
Artiodactyla
Suidae
Sus antiquus
Listriodon sp.
Cervidae
Dorcatherium naui
Flora by Wenz (1921)
Quercus furcinervus
Quercus undulans
Fagus deukalionis
Fagus castaneaefolia
Laurophyllum crassifolium
Aralites lanceus
Bumelia oreadum
Flora by Koenigswald (1929) [palynological]
Cinnamonum sp.
Taxodium sp.
Sequoia sp.

(2) Dorn-Dürkheim (West Germany)

This fauna indicates Turolian fauna (MN 11). Faunal list of the Dorn-Dürkheim Fauna is as follows (Tobien, 1980).

Mammalia
Rodentia
Sciuridae
Spermophilinus sp.
Pliopetaurista bressana
Pliopetes sp.
Blackia sp.
Miopetaurista sp.
Castoridae
Dipoides problematicus
Palaeomys castoroides
Palaeomys plassi n. sp.
Trogontherium minutum rhenanum n. sp.
Castor neglectus
Cricetidae
Epimeriones austriacus
Kowalskia sp. cf. *lavocati*
Collimys sp. cf. *primus*
Cricetulodon sp.
Anomalomyidae
Prospalax petteri

Pterospalax sp.
Muridae
Parapodemus lugdunensis
Zapodidae
Sminthozapus sp
Gliridae
Muscardinus vireti
Glis sp. cf. *minor*
Microdyromys sp.
Carnivora
Hyaenidae
Percrocuta eximia
Mustelidae
Martes sp. cf. *sansaniensis*
Martes sp.
Promeles sp. D
Felidae
Pseudaelurus tournauensis
Machairodus taracliensis
Felidarum inc. subfam.
Proboscidea
Gomphotheriidae
Tetralophodon longirostris
Deinotheriidae
Deinotherium giganteus

(3) Mt. Lebéron (France)

This fauna is Turolian fauna (MN 13). Faunal list of the Mt. Lebéron Fauna is as follows (Bernor & Pavlakis, 1987).

Mammalia
Carnivora
Viverridae
Herpestes guerini
Hyaenidae
Percrocuta eximia
Thallasictis wongii
Plioviverrops pentelici
Felidae
Machairodus aphanistus
Perissodactyla
Equidae
Hipparion prostylum
Rhinocerotidae
Aceratherium sp.
Dicerorhinus schleiermacheri
Artiodactyla

Suidae
Microstonyx erymanthius
Cervidae
Dremotherium sp.

4. Sub-Paratethys

Many localities of mammalian fauna are known from the late Miocene in Sub-Paratethys. The following mammalian faunas are represented as Turolian faunas (Pikermi, Samos and Maragheh).

(1) Pikermi (Greece)

This fauna is famous Turolian fauna (MN 12) of Greece (Wagner 1857; Solounias, 1981). Faunal list of the Pikermi Fauna is as follows (Solounias, 1981).

Mammalia
Insectivora
Talpidae
Uropsilinae
Desmanella dubia
Erinaceidae
Gymnurinae
Galerix atticus
Galerix moedlingensis
Primates
Cercopithecidae
Colobinae
Mesopithecus pentelici
Lagomorpha
Ocotonidae
Proloagus cf. *crusafonti*
Leporidae
Alilepus sp.
Rodentia
Cricetidae
Cricetinae
Kowalskia cf. *lavocati*
Cricetodontinae Tribe Cricetodontini
Byzantinia pikermiensis
Muridae
Murinae
Parapodemus gaudryi
Occitanomys ? *neutrum*
Occitanomys ? *provocator*
Gliridae
Glirinae
Muscardinus sp.

Myomimus cf. *dehmi*
Hystricidae
Hystricinae
Hystrix primigenia
Carnivora
Family indet.
Simocyon primigenium
Ursidae
Indarctos atticus
Mustelidae
Mustelinae
Sinictis pentelici
Martes woodwardi
?Plesiogulo sp.
Melinae
Promeles palaeattica
Mephitinae
Promephitis lartetii
Lutrinae
?Enhydriodon laticeps
Hyaenidae
Ictitheriinae
Plioviverrops orbignyi
Ictitherium viverrinum
Thalassictis hyaenoides
Thalassictis (*Lycyaena*) *chaeretis*
Thalassictis (*Lycyaena*) sp. nov. (by Solounias 1981)
Subfamily indet.
Hyaenictis graeca
Hyaenictis eximia
Felidae
Felinae
Felis sp.
Felis attica
Subfamily indet.
Metailurus parvulus
Metailurus major
Machairodontinae
Machairodus giganteus
Paramachairodus orientalis
Proboscidea
Palaeomastodontidae
Mammut borsoni ?
Gomphotheriidae
Gomphotheriinae
Stegotetrabelodon grandincisivus
Choerolophodon pentelici

- Deinotheriidae
  - *Deinotherium* cf. *giganteum*
- Hyracoidea
  - Procaviidae
    - *Pliohyrax graecus*
- Perissodactyla
  - Equidae
    - *Hipparion* sp. (large, one preorbital fossa)
    - *Hipparion minus* ? (small, one preorbital fossa)
    - *Hipparion proboscideum* (large, two preorbital fossae)
    - *Hipparion matthewi* (small, no preorbital fossa)
  - Chalicotheriidae
    - *Chalicotherium goldfussi*
  - Rhinocerotidae
    - Aceratheriinae Tribe Aceratherini
      - *Aceratherium* cf. *incisivum*
    - Rhinocerotinae Tribe Rhinocerotini
      - *Dicerorhinus schleiermacheri*
      - *Dicerorhinus pachygnathus*
- Artiodactyla
  - Suidae
    - *Sus* sp.
    - *Microstonyx erymanthius*
  - Cervidae
    - Cervinae
      - Cervinae gen. et sp. indet.
      - *Pliocervus pentelici*
  - Giraffidae
    - Palaeotraginae
      - *Palaeotragus rouenii*
    - Sivatheriinae
      - *Helladotherium duvernoyi*
    - Giraffinae
      - *Honanotherium speciosum*
      - *Honanotherium atticum*
  - Bovidae
    - *Miotragocerus-Tragoportax* complex
      - *Miotragocerus monacensis* var. A
      - *Miotragocerus monacensis* var. B
      - *Miotragocerus valenciennesi*
      - *Tragoportax amalthea*
      - *Tragoportax rugosifrons* ?
    - Tribe Antilopini
      - *Prostrepsiceros rotundicornis* var. A
      - *Protragelaphus skouzesi*
      - *Gazella capricornis*
      - *Oioceros rothi*

Tribe Ovibovini
Palaeoreas lindermayeri
Protoryx complex
Palaeoryx pallasi var. A
Palaeoryx pallasi var. C
Palaeoryx pallasi var. D
Sporadotragus parvidens
Protoryx carolinae
Tribe Tragelaphini
Selenoportax sp.

(2) Samos (Greece)

This fauna is a typical Sub-Paratethys Turolian (MN 12, 13) fauna. Richness of hyaenid, equid and bovid taxa shows an open-country fauna. The bone bearing horizons on Samos Island is comparable to age of between 8.5 and 9.0 Ma by K-Ar dating method (Solounias, 1981). Faunal list of the Samos Fauna is as follows (Solounias, 1981).

Mammalia
Insectivora
Erinaceidae
Gymnurinae
Galerix atticus
Chiroptera
Vespertilionidae
Vespertilioninae
Samonycteris majori
Primates
Cercopithecidae
Colobinae
Mesopithecus pentelici
Rodentia
Sciuridae
Spermophilinus cf. *bredai*
Cricetidae
Cricetodontinae Tribe Cricetodontini
Byzantinia hellenicus
Gerbillinae
Pseudomeriones pythagorasi
Muridae
Murinae
Occitanomys ? *provocator*
Spalacinae
Pliospalax cf. *sotirisi*
Hystricidae
Hystricinae
Hystrix primigenia

Carnivora
- Ursidae
  - *Ursavus* cf. *depereti*
  - *Indarctos atticus*
- Mustelidae
  - Melinae
    - *Promeles palaeattica*
    - *Promeles maraghana*
  - Mephitinae
    - *Promephitis lartetii*
- Hyaenidae
  - Ictitheriinae
    - *Plioviverrops orbignyi*
    - *Ictitherium viverrinum*
    - *Thalassictis wongii*
    - *Thalassictis hyaenoides*
    - *Thalassictis* (*Lycyaena*) *chaeretis*
    - *Thalassictis* (*Lycyaena*) sp. nov. (by Solounias 1981)
  - Subfamily indet.
    - *Hyaenictis eximia*
- Felidae
  - Felinae
    - *Felis attica*
  - Subfamily indet.
    - *Metailurus parvulus*
    - *Metailurus major*
  - Machairodontinae
    - *Machairodus giganteus*

Tubulidentata
- Orycteropodidae
  - *Orycteropus gaudryi*

Proboscidea
- Palaeomastodontidae
  - *Mammut borsoni?*
- Gomphotheriidae
  - Gomphotheriinae
    - *Stegotetrabelodon grandincisivus*
    - *Choerolophodon pentelici*
- Deinotheriidae
  - *Deinotherium* cf. *giganteum*

Hyracoidea
- Procaviidae
  - *Pliohyrax graecus*
  - *Pliohyrax kruppii*

Perissodactyla
- Equidae
  - *Hipparion* sp. (large, one preorbital fossa)

Hipparion minus (small, one preorbital fossa)
Hipparion proboscideum (large, two preorbital fossae)
Hipparion dietrichi (medium, no preorbital fossa)
Hipparion matthewi (small, no preorbital fossa)
Chalicotheriidae
Ancylotherium pentelicum
Rhinocerotidae
Aceratheriinae Tribe Aceratherini
Chilotherium samium
Chilotherium schlosseri
Chilotherium kowalewski
Rhinocerotinae Tribe Rhinocerotini
Dicerorhinus schleiermacheri
Dicerorhinus pachygnathus
Artiodactyla
Suidae
Microstonyx erymanthius
Potamochoerus hytheriordes
Tragulidae
Dorcatherium naui
Cervidae
Muntiacinae
Muntiacus sp.
Cervinae
Cervinae gen. et sp. indet.
Pliocervus pentelici
Giraffidae
Palaeotraginae
Palaeotragus rouenii
Palaeotragus coelophrys
Samotherium boissieri
Sivatheriinae
Helladotherium duvernoyi
Helladotherium sp. nov. (by Solounias, 1981)
Giraffinae
Honanotherium speciosum
Bovidae
Miotragocerus-Tragoportax complex
Miotragocerus monacensis var. A
Miotragocerus monacensis var. B
Miotragocerus valenciennesi
Tragoportax amalthea
Tragoportax curvicornis
Tragoportax rugosifrons
Samokeros minotaurus var. A
Samokeros minotaurus var. B
Tribe Antilopini

Prostrepsiceros rotundicornis var. B
Prostrepsiceros houtumschindleri var. A
Protragelaphus skouzesi
Gazella capricornis
Gazella mytilinii
Gazella dorcadoides
Oioceros wegneri
Sinotragus crassicornis
Prosinotragus kuhlmanni
Prosinotragus sp. nov. (by Solounias, 1981)
Tribe Ovibovini
Palaeoreas lindermayeri
Criotherium argalioides
Parurmiatherium rugosifrons
Protoryx complex
Palaeoryx pallasi var. B
Palaeoryx pallasi var. C
Palaeoryx pallasi var. D
Tragoreas oryxoides
Sporadotragus parvidens
Protoryx crassicornis var. A (long-brained)
Protoryx crassicornis var. B (short-brained)
Protoryx laticeps var. A (long-brained)
Protoryx laticeps var. B (short-brained)
Pseudotragus capricornis
Tribe Rupicaprini
gen. et sp. indet.

(3) Maragheh (Iran)

This fauna is a typical Turolian fauna of Sub-Paratethys (Mecquenem, 1908-1911, 1924-25; Kamei et al., 1977; Bernor et al., 1980; Solounias, 1981; Bernor, 1986). The Maragheh Formation is comparable to age of between 7 and 11 Ma by K-Ar dating method (Bernor et al., 1980). Faunal list of the Samos Fauna is as follows (Solounias, 1981).

Mammalia
Primates
Cercopithecidae
Colobinae
Mesopithecus pentelici
Rodentia
Muridae
Murinae
?*Gerboa* sp.
Carnivora
Ursidae
Indarctos atticus

- Mustelidae
  - Mustelinae
    - *Martes* sp.
  - Melinae
    - *Promeles palaeattica*
    - *Parataxidea maraghana*
    - *Parataxidea polaki*
- Hyaenidae
  - Ictitheriinae
    - *Thalassictis wongii*
  - Subfamily indet.
    - *Hyaenictis eximia*
- Felidae
  - Felinae
    - *Felis attica*
  - Subfamily indet.
    - *Metailurus parvulus*
  - Machairodontinae
    - *Machairodus giganteus*
    - *Paramachairodus orientalis*

Tubulidentata
- Orycteropodidae
  - *Orycteropus gaudryi*

Proboscidea
- Gomphotheriidae
  - Gomphotheriinae
    - *Choerolophodon pentelici*

Perissodactyla
- Equidae
  - *Hipparion* sp. (large, one preorbital fossa)
  - *Hipparion minus* (small, one preorbital fossa)
  - *Hipparion dietrichi* (medium, no preorbital fossa)
- Chalicotheriidae
  - *Ancylotherium pentelicum*
- Rhinocerotidae
  - Aceratheriinae Tribe Aceratherini
    - *Chilotherium persiae*
  - Rhinocerotinae Tribe Rhinocerotini
    - *Diceros pachygnathus*
  - Rhinocerotinae Tribe Elasmotherini
    - *Iranotherium morgani*

Artiodactyla
- Suidae
  - *Microstonyx erymanthius*
- Cervidae
  - Cervinae
    - *Pliocervus pentelici*

Giraffidae
Palaeotraginae
Palaeotragus coelophrys
Samotherium boissieri
Sivatheriinae
Helladotherium duvernoyi
Giraffinae
Honanotherium atticum
Bovidae
Miotragocerus-Tragoportax complex
Miotragocerus monacensis var. B
Samokeros minotaurus var. A
Tribe Antilopini
Prostrepsiceros rotundicornis var. B
Prostrepsiceros houtumschindleri var. B
Protragelaphus skouzesi
Gazella deperdita
Oioceros rothi
Oioceros atropatenes
Oioceros rodleri
Sinotragus sp. nov. (Solounias, 1981)
Tribe Ovibovini
Urmiatherium polaki
Protoryx complex
Protoryx crassicornis var. A (long-brained)
Protoryx crassicornis var. B (short-brained) ?
Protoryx laticeps var. A (long-brained)
Protoryx laticeps var. B (short-brained) ?

5. Siwaliks

Many localities of mammalian fauna are known from the late Miocene in Siwaliks. The following mammalian faunas are represented as Astaracian fauna (Chinji), late Vallesian to early Turolian fauna (Nagri) and late Turolian fauna (Dhok Pathan).

(1) Chinji (Pakistan)

This fauna have none of cervids and Hipparion. Overall faunal resemblances are to Astaracian faunas of Eurasia. An age of between 11 and 13 Ma. Faunal list of the Chinji Fauna is as follows (Pilbeam et al., 1977).

Mammalia
Primates
Hominoidea
Sivapithecus sivalensis
Sivapithecus indicus
Ramapithecus punjabicus
Creodonta
Hyaenodontidae

Hyainailouros bugtiensis
Dissopsalis carnifex
Rodentia
Rhizomyidae
cf. Rhizomyidae gen. et sp. indet
Cricetidae
Copemys sp.
Megacricetodon sp.
Muridae
Antemus chinjiensis
Carnivora
Amphicyonidae
Amphicyoninae (large sp.)
Amphicyon sp.
Vishnucyon chinjiensis
Mustelidae
Martes lydekkeri
?*Martes* sp.
Vishnuonyx chinjiensis
Mustelinae sp.
Viverridae
?*Viverra chinjiensis*
Hyaenidae
Hyaenidae gen. et sp. indet.
Percrocuta carnifex
Felidae
'Sivasmilus' (=Paramachairodus copei)
Sivaelurus chinjiensis
Felidae gen. et sp. indet.
?*Sansanosmilus* sp.
Tubulidentata
Orycteropodidae
Orycteropus sp.
Perissodactyla
Chalicotheriidae
Chalicotherium salinum
Rhinocerotidae
Rhinocerotidae spp.
Artiodactyla
Suidae
Listriodon pentapotamiae
Conohyus chinjiensis
Lophochoerus sp.
Merycopotamus pusillus
Dorcabune nagrii
Tragulidae
Tragulidae spp.

Giraffidae
Giraffokeryx sp.
Bovidae
Protragocerus gluten
Miotragocerus gradiens
Kubanotragus sokolovi
?Pseudotragus potwaricus
Sivoreas eremita
Gazella sp.

(2) Nagri (Pakistan)

The bovids, suids, rodents and the two species of Hipparion of this fauna suggest a correlation with late Vallesian or early Turolian faunas. Upper half of Nagri Formation is probably comparable to age of between 9 and 10 Ma with age of Samos and Turkish faunas. The lower half of Nagri Formation suggests earlier Vallesian. Faunal list of the Nagri Fauna is as follows (Pilbeam et al., 1977).

Mammalia
Insectivora
Soricidae
gen. et sp. indet.
Primates
?Lorisidae
gen. et sp. indet.
Hominoidea
Sivapithecus sivalensis
Sivapithecus indicus
Ramapithecus punjabicus
cf. *Gigantopithecus* sp.
Rodentia
Sciuridae
gen. et sp. indet.
Gliridae
gen. et sp. indet.
Rhizomyidae
Rhizomyoides sp.
Kanisamys sivalensis
Muridae
Progonomys n. sp.
Parapodemus sp.
cf. *"Mastomys" colberti*
Creodonta
Hyaenodontidae
cf. *Isohyaenodon* sp.
Carnivora
Amphicyonidae
Amphicyon sp.

- Mustelidae
  - ?*Martes* sp.
  - Mustelinae sp.
  - *Eomellivora* sp.
  - *Sivaonyx bathygnathus*
- Viverridae
  - Viverrinae 2 sp.
  - ?Herpestinae sp.
  - ?*Progenetta* sp.
- Hyaenidae
  - *Palyhyaena sivalensis*
  - ?*Miohyena* n. sp.
  - *Percrocuta carnifex*
  - *Percrocuta grandis*
- Felidae
  - ? *Sivaelurus* sp.
  - Machairodontinae

Proboscidea
- Gomphotheriidae
  - gen. et sp. indet.
- Deinotheriidae
  - *Deinotherium* sp.

Perissodactyla
- Equidae
  - *Hipparion* small and large spp.
- Chalicotheriidae
  - *Chalicotherium* cf. *salinum*

Artiodactyla
- Suidae
  - *Propotamochoerus hysudricus*
  - *Propotamochoerus* sp.
  - *Conotyus* sp.
  - *Tetraconodon* sp.
  - *Hippopotamodon sivalense (=Dicryphochoerus titan)*
- Tayassuidae
  - *Schizochoerus* sp.
- Anthracotheriidae
  - *Merycopotamus namus*
  - *Merycopotamus dissimilis*
- Tragulidae
  - *Dorcabune nagrii*
  - *Dorcatherium majus*
  - *Dorcatherium minus*
  - cf. *Dorcatherium* sp.
- Giraffidae
  - cf. *Sivatherium* sp.
- Bovidae

Gazella sp.
Miotragocerus punjabicus
Selenoportax vexillarius
?*Pseudotragus* sp.
Boselaphini very small gen. et sp. nov.

(3) Dhok Pathan (Pakistan)

The Dhok Pathan fauna resembles those from late Turolian in Eurasia and North Africa. The Dhok Pathan Formation is probably comparable in age of between 8 and 9 Ma (or perhaps less) with age of Samos and Turkish faunas. Faunal list of the Dhok Pathan Fauna is as follows (Colbert, 1935; Pilbeam et al., 1977).

Mammalia
Primates
Cercopithecidae
Cercopithecus hasnoti
Macaca sivalensis
Hominoidea
Dryopithecus frickae

Rodentia
Rhizomyidae
Rhizomyoides sp.
Kanisamys sivalensis
Hystricidae
Hystrix sivalensis
Carnivora
Amphicyonidae
Amphicyon lydekkeri
Ursidae
Agriotherium palaeindicum
Indarctos salmontanus
Indarctos punjabiensis
Mustelidae
?*Martes* sp.
Mustelinae sp.
Eomellivora sp.
Sivaonyx bathygnathus
Viverridae
Viverrinae 2 sp.
?*Herpestinae* sp.
?*Progenetta* sp.
Hyaenidae
Palyhyaena sivalensis
?*Miohyena* n. sp.
Percrocuta carnifex
Percrocuta grandis

Felidae
? *Sivaelurus* sp.
Machairodontinae
Proboscidea
Gomphotheriidae
gen. et sp. indet.
Deinotheriidae
Deinotherium sp.
Perissodactyla
Equidae
Hipparion small and large spp.
Chalicotheriidae
Chalicotherium cf. *salinum*
Artiodactyla
Suidae
Propotamochoerus hysudricus
Propotamochoerus sp.
Conotyus sp.
Tetraconodon sp.
Hippopotamodon sivalense (=Dicryphochoerus titan)
Tayassuidae
Schizochoerus sp.
Anthracotheriidae
Merycopotamus namus
Merycopotamus dissimilis
Tragulidae
Dorcabune nagrii
Dorcatherium majus
Dorcatherium minus
cf. *Dorcatherium* sp.
Giraffidae
cf. *Sivatherium* sp.
Bovidae
Gazella sp.
Miotragocerus punjabicus
Selenoportax vexillarius
?*Pseudotragus* sp.
Boselaphini very small gen. et sp. nov.

6. China

Many localities of mammalian fauna are known from the late Miocene in China. The following mammalian faunas are represented as early Turolian fauna (Baode) and late Turolian fauna (Yushe I).

(1) Baode, Shanxi

This fauna is correlated with early Turolian mammalian age of West Eurasia and richness of hyaenid, equid and bovid taxa indicate open-country environments. Faunal

list of the Baode Fauna is as follows (Yen et al. eds., 1984; Qiu et al., 1987).

Mammalia
Rodentia
Castoridae
Sinocastor zdanskyi
Carnivora
Amphicyonidae
Amphicyon sp.
Ursidae
Sinocyon cf. *primigenium*
Indarctos lagrelii
I. sinensis
Mustelidae
Eomellivora wimani
Lutra aonychoides
Martes palaeosinensis
Melodon incertum
Melodon major
Parataxidea crassa
Parataxidea sinensis
Plesiogulo brachygnathus
Proputorius minimus
Sinictis dolichognathus
Hyaenidae
Hyaena honanensis
Hyaena variabilis
Ictitherium gaudryi
Ictitherium hyaenoides
Ictitherium sinensis
Ictitherium wongi
Lycyaena dubia
Felidae
Homotherium palanderi
Homotherium tingi
Pseudaelurus major
Pseudaelurus minor
Proboscidea
Gomphotheriidae
Tetralophodon exoletus
Perissodactyla
Equidae
Hipparioninae
Hipparion (Hipparion) dermatorhinum
Hipparion (Hipparion) fossatum
Hipparion (Hipparion) hippidiodus
Hipparion (Hipparion) placodus

Anchitheriinae
Sinohippus ziteli
Rhinocerotidae
Aceratheriinae
Chilotherium anderssoni
Chilotherium gracile
Chilotherium habereri
Chilotherium planifrons
Chilotherium samium
Chilotherium schlosseri
Chilotherium wimani
Rhinocerotinae
Dicerorhinus orientalis
Iranotheriinae (Elasmotheriinae)
Sinotherium lagrelii
Artiodactyla
Suidae
Chleuastochoerus stehlini
Potamochoerus hytheriordes
Sus erymanthius
Cervidae
Cervavitus novorossiae
Procapreolus latifrons
Giraffidae
Palaeotragus cf. *coelophrys*
Palaeotragus microdon
Samotherium sinense
Bovidae
Paraprotoryx minor
Miotragocerus-Tragoportax complex
Tragocerus gregarius
Tragocerus lagrelii
Tragocerus spectabilis
Gazella altidens
Gazella dorcadoides
Gazella gaudryi
Gazella paotehensis
Sinotragus wimani
Plesiadax depereti
Plesiadax minor
Urmiatherium intermedium
Protoryx shansiensis

(2) Yushe Zone I, Shanxi

This fauna is correlated with late Turolian mammalian age of West Eurasia and indicates woodland environments. Faunal list of the Yushe Zone I Fauna is as follows (Yen et al. eds., 1984; Qiu et al., 1987).

Mammalia
Rodentia
Castoridae
Sinocastor zdanskyi
Cricetidae
Prosiphneus murinus
Carnivora
Ursidae
Sinocyon cf. *primigenium*
Hyaenarctis sp.
Mustelidae
Lutra aonychoides
Martes palaeosinensis
Plesiogulo brachygnathus
Hyaenidae
Ictitherium gaudryi
Felidae
Homotherium palanderi
Pseudaelurus major
Pseudaelurus minor
Felis sp.
Proboscidea
Gomphotheriidae
Gomphotherium wimani
Tetralophodon exoletus
Tetralophodon sp.
Anancus cuneatus
Anancus sinensis
Selenolophodon spectabilis
Stegodontidae
Stegodon yushensis
Perissodactyla
Equidae
Hipparioninae
Hipparion (Hipparion) platyodus
Tapiridae
Tapirus teilhardi
Rhinocerotidae
Rhinocerotinae
Dicerorhinus orientalis
"*Dicerorhinus palaeosinensis*"
Artiodactyla
Suidae
Chleuastochoerus stehlini
Sus erymanthius
Cervidae

Axis speciosus
Eostyloceros blainvillei
Eostyloceros triangularis
Procapreolus latifrons
Cervavitus demissus
Cervavitus novorossiae
Procapreolus latifrons
Giraffidae
Palaeotragus decipens
Palaeotragus sp.
Honanotherium schlosseri
Bovidae
Dorcadoryx triguetricornis
Paraprotoryx killgusi
Sinoryx bombifrons
Tragocerus laticornis
Gazella gaudryi
Oioceros sp.
Protoryx bohlini
Protoryx yushensis
Tragoreas palaeosinensis

In the discussion section, The author analyses faunal resemblance from the evidence of well over 500 taxa of 22 Eurasian faunas shown in Appendix 1 (p. 103–112).

IV. Neogene Faunal Aspects and Paleoecology of Sub-Saharan Africa

The geographical distribution and paleoecology of Sub-Saharan faunas in each age is remarked in the following chapter (Fig. 9).

The following zonation of Sub-Saharan Africa is based largely on the radiometric age and faunal resemblance (Benefit & Pickford, 1986; Nakaya, 1987, 1989, 1993; Nakaya et al., in press; Pickford, 1981, 1982, 1986a, 1986b; this work). East African mammalian faunas are described in the following chapter (p. 50–75) in detail.

1. Miocene

(1) Agenian

The following Agenian (18-22 Ma) mammalian faunas are sporadically distributed in South Africa, Zaire and East Africa. Correlation of the Faunal Sets of East Africa is followed after Pickford (1981).

Pre Set I (early Agenian); Meswa (Kenya).

Set I (late Agenian); Malembe (Zaire: Hooijer, 1963, 1970), Napak (Uganda), Koru (Kenya), Songhor (Kenya), Kiahera (Kenya), Chemtwara (Kenya).

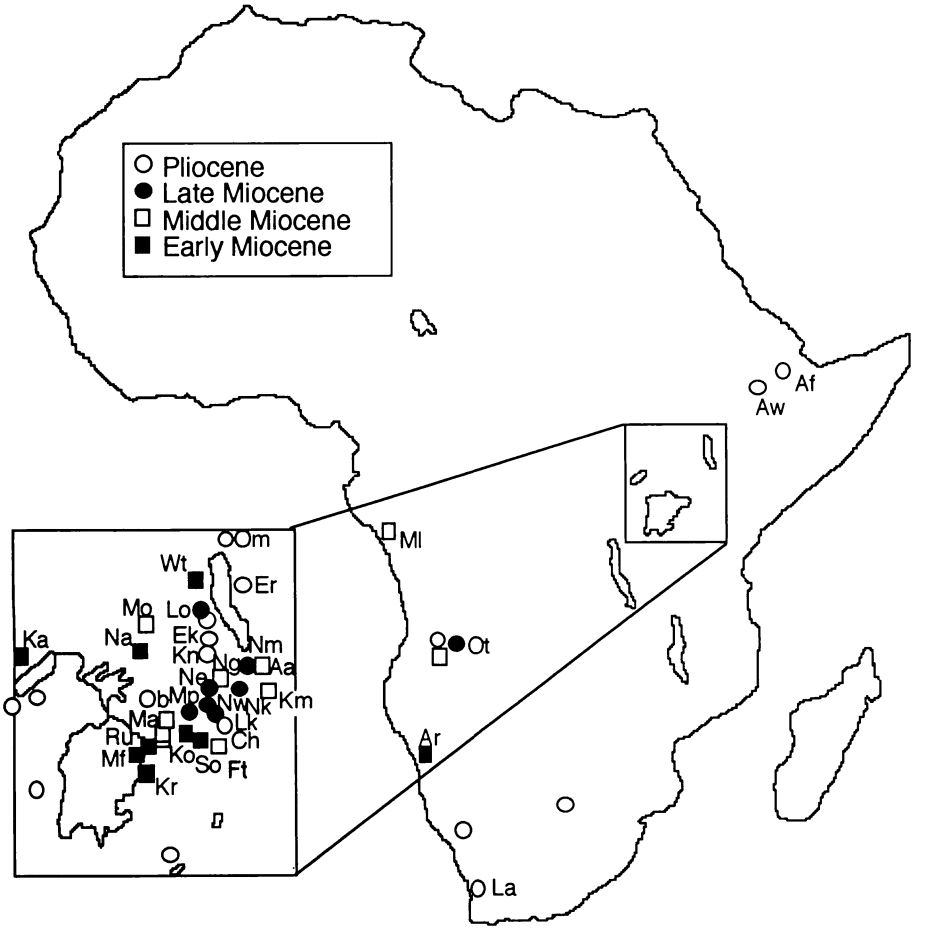


Fig. 9. Neogene vertebrate localities from the Sub-Saharan Africa.
Aa: Aka Aiteputh; Af: Afar; Ar: Arrisdrift; Aw: Middle Awash; Ch: Chemeron; Ek: Ekora; Er: East Rudolf; Ft: Fort Ternan; Ka: Karugamania; Km: Kirimun; Kn: Kanapoi; Ko: Koru; Kr: Karungu; La: Langebaanweg; Lk: Lukeino; Lo: Lothagam; Na: Napak; Ne: Ngorora E; Ng: Ngorora; Nk: Nakali; Nm: Namurungule; Nw: Ngeringerowa; Ma: Maboko; Mf: Mfwangano; Ml: Malembe; Mo: Moroto; Mp: Mpesida; Ob: Ombo; Om: Omo; Ru: Rusinga; Ot: Otavi; So: Songhor; Wt: West Turkana.

(2) Orleanian

The following Orleanian (15-18 Ma) mammalian faunas are sporadically distributed in South Africa and East Africa. Correlation of the Faunal Sets of East Africa is followed after Pickford (1981). Some fauna are characterized by dominant Primates (Maboko Fauna).

Set II (early Orleanian); Hiwegi, Gumbo, Chianda (Rusinga Island, Kenya), Bukwa (Kenya), Moruorot (Kenya), Karungu (Kenya), Mfwangano (Kenya).

Set III (late Orleanian); Arrisdrift (Namibia; South West Africa early middle Miocene 14-18 Ma; Hendey, 1978), Ombo (Kenya), Maboko (Kenya), Buluk (Kenya), Loperot (Kenya), Kirimun (Kenya), Majiwa (Kenya).

(3) Astaracian

The following Astaracian (12.5-15 Ma) mammalian faunas are sporadically distributed in East Africa only. Correlation of the Faunal Sets of East Africa is followed after Pickford (1981). Some fauna are characterized by dominant Primates (Aka Aiteputh Fauna).

Set IV (Astaracian); Moroto (Uganda), Aka Aiteputh (Kenya), Fort Ternan (Kenya), Muryur (Kenya), Otavi BA-1, 47, 63, (Namibia: Conroy et al., 1992).

(4) Vallesian

The Vallesian (10.5-12.5 Ma) mammalian faunas are distributed in East Africa only. Hipparion appeared about 12.5 Ma in Sub-Saharan Africa. The Ngorora Fauna has rich assemblage.

Set V (Vallesian); Ngorora (Kenya), Otavi BA-31, 90 (Namibia: Conroy et al., 1992).

(5) Turolian

The following Turolian (5.5-10.5 Ma) mammalian faunas are sporadically distributed in East Africa only. This fauna is considered as a core of the Sub-Saharan mammalian faunas after Miocene. The mammalian assemblage of Sub-Saharan African faunas changed since late Astaracian. Some recent genera of mammals appeared in East Africa, in post-Vallesian age. Therefore, the Namurungule Fauna is very important, from the viewpoint of the process of the environmental change during the late Miocene and the effects of this paleoenvironmental change to the Hominoid evolution. Table 3 shows a list of taxa of the Ngorora Fauna of the Vallesian, the Nakali, Ngeringerowa, Ngorora E Formation (Benefit & Pickford, 1986) and Namurungule Fauna (Nakaya et al., in press; Kawamura & Nakaya, in press) of the Turolian East Africa. The Namurungule Fauna has rich assemblage among the Turolian faunas, however, other faunas have poor assemblage.

Set VI (early Turolian); Ngorora upper E (Kenya), Ngeringerowa (Kenya), Nakali (Kenya), Namurungule (Kenya).

Set VII (late Turolian); Mpesida (Kenya), Lukeino (Kenya) and Lothagam I (Kenya).

2. Pliocene

(1) Ruscinian

The following Ruscinian (3.5-5.5 Ma) mammalian faunas are distributed in East Africa and South Africa. The first family Hominidae (*Australopithecus*) appeared in these faunas.

Set VIII (Ruscinian); Afar (Ethiopia), Middle Awash (Ethiopia), Chemeron (Kenya), Ekora (Kenya), Kanapoi (Kenya), Lothagam (Kenya), Laetoli (Tanzania), Otavi BA-8, 54 (Namibia: Conroy et al., 1992), Langebaanweg (South Africa).

Table 3. A list of taxa of each fauna of the Vallesian to early Turolian mammalian faunas of East Africa.

Taxa / Locality	NM	NG	NE	NK	NW
Hominoidea small form		1			
Hominoidea large form	1	1			
Cercopithecoidea indet.		1			
Colobinae sp.				1	
Microcolobus tugenensis					1
Agnotherium sp.		1			
Eomellivora sp.		1			
Sivaonyx sp.		1			
Hyaenidae (*Percrocuta* sp.)	1	1			
Canidae small sp.		1			
Orycteropus chemeldoi	?	1			
Choerolophodon ngorora		1	1	?	
Tetralophodon sp.	1	1			
Deinotherium sp. cf. *bozasi*	1	1		1	1
Parapliohyrax sp.		1	1		
Hipparion large form	1		1	1	1
Hipparion small form	1				
Ancylotherium sp. ?	1				
Aceratherium/Dicerorhinus sp.		1			
Chilotheridium pattersoni	1	1			
Paradiceros sp.	1				
Brachypotherium lewisi		1			
Kenyatherium bishopi	1			1	
?*Conohyus* sp.		1			
Lopholistriodon kidogosana		1			
Nyanzachoerus sp.	1		1	1	
Tayassuidae		1			
Kenyapotamus coryndoni	1	1	1		1
Kenyapotamus sp.				1	
Dorcatherium pigotti		1			1
Palaeotragus sp.	1	1	1	?	1
Giraffidae large form(*Samotherium* sp.)	1	1			
Climacoceras gentryi		1			
Protragocerus labidotus		1			
Sivoreas/Palaeoreas sp.	1	1			1
Hippotraginae/Reduncini				1	1
Homoiodorcas tugenium		1			
?*Antidorcas* sp.		1			1
Pseudotragus? *gentryi*		1	1		
Pachytragus sp.	1	1			
Gazella sp.	1				
Paraphiomys pigotti	1				
Paraulacodus sp.	1				

Note: NG: Ngorora A-D; NE: Ngorora Upper E; NK: Nakali; NW: Ngeringerowa (Benefit & Pickford, 1986); NM: Namurungule (Nakaya et al., in press; Kawamura & Nakaya., in press).

V. Development of Neogene Mammals in East Africa

The age of some Neogene mammalian sites from East Africa has been determined by radiometric dating methods. The age of many sites were determined by stratigraphical correlation and faunal resemblance. The following description shows mammalian assemblages, age (radiometric and so on), and paleoenvironment at each location (country).

(1) Meswa (Kenya)

The age of this fauna was determined as Faunal Set Pre-Set I by faunal assemblages and this fauna must have inhabited in subaerial environments deduced from sedimentological evidence (Andrews et al., 1981; Pickford, 1986a). Faunal list of the Meswa Fauna is following Pickford (1986a).

Mammalia
Primates
Oreopithecidae gen. nov.
Artiodactyla
Walangania africanus

(2) Napak (Uganda)

The age of this fauna was determined as 19-25 Ma by K-Ar dating and as Faunal Set I by faunal assemblages and this fauna must have inhabited in subaerial environments deduced from sedimentological evidence (Bishop, 1962, 1967; Pickford, 1981). Faunal list of the Napak Fauna is as follows (Bishop, 1962, 1967).

Mammalia
Insectivora
Miohyncocyon clarki
Myohyrax oswaldi
Hiwagicyon juvenalis
Parageogale aletris
Protenrec tricuspis
Gymnuechinus leakeyi
Gymnuechinus camptolophus
Amphechinus rusingensis
Galerix africanus
Propotto leakeyi
Molossidae sp. nov.
Emballonuridae gen. et sp. indet.
Megalodermatidae gen. et sp. indet.
Komba minor
Komba robustus
Primates
Progalago songhorensis
Mioeuoticus sp.
Dendropithecus macinnesi

Limnopithecus legetet
Proconsul africanus
Proconsul nyanzae
Rangwapithecus gordoni
Nyanzapithecus vancouveringi

Rodentia
Kenyalagomys rusingae
Kenyalagomys minor
Paraphiomys pigotti
Paraphiomys stromeri
Epiphiomys coryndoni
Elimerimys woodi
Diamantomys leuderitzi
Kenyamys mariae
Simonimys genovefae
Myophiomys arambourgi
Ploheliophobius leakeyi
Paranomalurus soniae
Paranomalurus walkeri
Megapedetes pentadactylus
Pedetidae gen. et sp. nov.
Protarsomys macinnesi
Vulcanisciurus africanus
Teratodon enigmae
Pterodon nyanzae
Anasinopa leakeyi
Metapterodon kaiseri

Creodonta
Leakeytherium hiwegi
Hyaenodon andrewsi
Hyaenodon pilgrimi
Hecubides euryodon
Hecubides macrodon
Kichechia zamanae
Afrosmilus africanus

Tubulidentata
Myorycteropus africanus

Proboscidea
Prodeinotherium hobleyi
Archaeobelodon sp.
Eozygodon morotoensis

Hyracoidea
Pachyhyrax championi
Prohyrax bateae

Perissodactyla
Chalicotherium rusingense
Dicerorhinus leakeyi

Aceratherium acutirostratum
Brachypotherium heinzelini
Artiodactyla
Hyoboops africanus
Masritherium aequitoralis
Diamantohyus africanus
Libycochoerus jeanelli
Kenyasus rusingensis
Nguruwa kijivium
Dorcatherium chappuisi
Dorcatherium pigotti
Dorcatherium parvum
Canthumeryx sirtensis
Propalaeoryx nyanzae
Walangania africanus

(3) Koru (Kenya)

The age of this fauna was determined as Faunal Set I by faunal assemblages and this fauna must have inhabited in subaerial, apron of central volcano, and intermittent deposition with pedogenesis environments deduced from sedimentological evidence (Bishop, 1967; Pickford, 1981, 1986a). Faunal list of the Koru Fauna is as follows (Bishop, 1967).

Mammalia
Insectivora
Amphechinus rusingensis
Erythrozootes chamerpes
Prochrysochloris miocaenicus
Rhynchocyon clarki
Saccolaimus incognita
Primates
Progalago sp.
Limnopithecus legetet
Proconsul africanus
Proconsul nyanzae
Rodentia
Teratodon spekei
Hecubides euryodon
Proboscidea
Deinotherium sp.
Perissodactyla
Chalicotherium rusingense
Artiodactyla
Dorcatherium songhorensis
Palaeomeryx africanus

(4) Songhor (Kenya)

The age of this fauna was determined as Faunal Set I by faunal assemblages and this

fauna must have inhabited in subaerial, apron of central volcano, intermittent deposition with pedogenesis environments deduced from sedimentological evidence (Bishop, 1967; Pickford, 1981, 1986a). Faunal list of the Songhor Fauna is as follows (Bishop, 1967).

Mammalia
Insectivora
- *Rhynchocyon clarki*
- *Rhynchocyon rusingae*
- *Protenrec tricuspis*
- *Gymnuechinus songhorensis*
- *Amphechinus rusingensis*
- *Galerix africanus*
- *Prochrysochloris miocaenicus*

Primates
- *Progalago dorae*
- *Progalago robustus*
- *Progalago minor*
- *Limnopithecus legetet*
- *Limnopithecus macinnesi*
- *Proconsul africanus*
- *Proconsul nyanzae*
- *Proconsul major*

Rodentia
- *Paraphiomys pigotti*
- *Paraphiomys* small form
- *Diamantomys* sp.
- *Megapedetes pentadactylus*
- Pedetidae small form
- *Teratodon enigmae*
- *Teratodon spekei*
- *Bathyergoides* sp.
- *Cricetodon* sp.
- Anomaluridae large form
- Anomaluridae small form

Creodonta
- *Hyaenodon andrewsi*
- *Hyaenodon pilgrimi*
- *Hecubides matthewi*
- *Kichechia zamanae*

Carnivora
- *Metailurus africanus*
- *Hyotherium* sp.

Hyracoidea
- *Megalohyrax championi*
- *Myohyrax* sp.
- *Bunohyrax* sp.

Proboscidea
Gomphotherium sp.
Perissodactyla
Chalicotherium rusingense
Artiodactyla
Dorcatherium songhorensis
Palaeomeryx africanus

(5) Rusinga (Kenya)

The mean age of Rusinga Group was determined as 17.9 Ma (Hiwegi Formation: 16.9-34.5 Ma, Rusinga Agglomerate: 16.6-21.9 Ma, Kiahera Formation: 17.2-22.9 Ma) by K-Ar dating (Drake et al., 1988) and as Faunal Set II by faunal assemblages (Pickford, 1981). Faunal list of the Songhor Fauna is as follows (Drake et al., 1988).

Mammalia
Insectivora
Miohyncocyon clarki
Myohyrax oswaldi
Hiwagicyon juvenalis
Parageogale aletris
Protenrec tricuspis
Gymnuechinus leakeyi
Gymnuechinus camptolophus
Amphechinus rusingensis
Galerix africanus
Propotto leakeyi
Molossidae sp. nov.
Emballonuridae gen. et sp. indet.
Megalodermatidae gen. et sp. indet.
Komba minor
Komba robustus
Primates
Progalago songhorensis
Mioeuoticus sp.
Dendropithecus macinnesi
Limnopithecus legetet
Proconsul africanus
Proconsul nyanzae
Rangwapithecus gordoni
Nyanzapithecus vancouveringi
Rodentia
Kenyalagomys rusingae
Kenyalagomys minor
Paraphiomys pigotti
Paraphiomys stromeri
Epiphiomys coryndoni
Elimerimys woodi

Diamantomys leuderitzi
Kenyamys mariae
Simonimys genovefae
Myophiomys arambourgi
Ploheliophobius leakeyi
Paranomalurus soniae
Paranomalurus walkeri
Megapedetes pentadactylus
Pedetidae gen. et sp. nov.
Protarsomys macinnesi
Vulcanisciurus africanus
Teratodon enigmae
Pterodon nyanzae
Anasinopa leakeyi
Metapterodon kaiseri
Leakeytherium hiwegi
Hyaenodon andrewsi
Hyaenodon pilgrimi
Hecubides euryodon
Hecubides macrodon
Kichechia zamanae

Carnivora
Afrosmilus africanus

Tubulidentata
Myorycteropus africanus

Proboscidea
Prodeinotherium hobleyi
Archaeobelodon sp.
Eozygodon morotoensis

Hyracoidea
Pachyhyrax championi
Prohyrax bateae

Perissodactyla
Chalicotherium rusingense
Dicerorhinus leakeyi
Aceratherium acutirostratum
Brachypotherium heinzelini

Artiodactyla
Hyoboops africanus
Masritherium aequitoralis
Diamantohyus africanus
Libycochoerus jeanelli
Kenyasus rusingensis
Nguruwa kijivium
Dorcatherium chappuisi
Dorcatherium pigotti
Dorcatherium parvum

Canthumeryx sirtensis
Propalaeoryx nyanzae
Walangania africanus

(6) Karungu (Kenya)

The age of this fauna was determined as 17.5-17.7 Ma by K-Ar dating (Drake et al., 1988) and as Faunal Set II by faunal assemblages (Pickford, 1981). This fauna must have inhabited in lacustrine, lake margin and swamp, wet part of flood plain and large river system in volcanic arena deduced from sedimentological evidence (Pickford, 1981). Faunal list of the Karungu Fauna is as follows (Drake et al., 1988).

Mammalia
Primates
Dendropithecus macinnesi
Proconsul nyanzae
Rodentia
? *Kenyalagomys rusingae*
Paraphiomys pigotti
Paraphiomys stromeri
Diamantomys leuderitzi
Anasinopa leakeyi
Metapterodon kaiseri
? *Kichechia zamanae*
Carnivora
Afrosmilus africanus
Tubulidentata
Myorycteropus africanus
Orycteropus minutus
Proboscidea
Prodeinotherium hobleyi
Archaeobelodon sp.
Hyracoidea
Myohyrax oswaldi
Pachyhyrax championi
? *Prohyrax bateae*
Perissodactyla
Chalicotherium rusingense
Dicerorhinus leakeyi
Aceratherium acutirostratum
Brachypotherium heinzelini
Artiodactyla
Hyoboops africanus
Masritherium aequitoralis
Diamantohyus africanus
Libycochoerus jeanelli
Kenyasus rusingensis
Dorcatherium chappuisi

Dorcatherium parvum
? *Canthumeryx sirtensis*
Propalaeoryx nyanzae
Walangania africanus

(7) Mfwangano (Kenya)

The age of this fauna was determined as 21.7 Ma (Kiahera Formation) by K-Ar dating (Drake et al., 1988). This fauna must have inhabited in subaerial, apron of central volcano, intermittent deposition with pedogenesis, and dry part of floodplain in volcanic arena deduced from sedimentological evidence (Pickford, 1981). Faunal list of the Kiahera Formation of the Mfwangano Fauna is as follows (Drake et al., 1988).

Mammalia
Myohyrax oswaldi
Komba robustus
Primates
Dendropithecus macinnesi
Proconsul africanus
Proconsul nyanzae
Rodentia
Kenyalagomys rusingae
Paraphiomys pigotti
Paraphiomys stromeri
Diamantomys leuderitzi
Megapedetes pentadactylus
Hecubides euryodon
Proboscidea
Prodeinotherium hobleyi
Hyracoidea
? *Pachyhyrax championi*
Perissodactyla
Brachypotherium heinzelini
Artiodactyla
Masritherium aequitoralis
Kenyasus rusingensis
Nguruwa kijivium
Dorcatherium pigotti
Propalaeoryx nyanzae
Walangania africanus

(8) Buluk (Kenya)

The age of this fauna was determined as 17.3 Ma by K-Ar dating and as Faunal Set III by faunal assemblages. This fauna must have inhabited in in a shallow or intermittent aquatic environments and interdistributary or behind-shore lagoon facies deduced from sedimentological evidence (Harris & Watkins, 1974; Pickford, 1981). Faunal list of the Buluk Fauna is as follows (Harris & Watkins, 1974).

Reptilia
Crocodylia
Crocodylidae
gen. et sp. indet.
Testudines
gen. et sp. indet.
Mammalia
Creodonta
gen. et sp. indet.
Proboscidea
Platybelodon kisumuensis
Prodeinotherium hobleyi
Hyracoidea
Megalohyrax championi
Perissodactyla
Dicerorhinus sp.
Artiodactyla
Listriodon sp.

(9) Kirimun (Kenya)

The age of this fauna was determined as 11.5-15Ma by K-Ar and fission track dating and as Faunal Set III by faunal assemblages (Pickford, 1981). Sanithere and tragulid (Artiodactyla) indicates woodland environments (Kawamura & Nakaya, 1982; Pickford 1982; Matsuda et al., 1986). Faunal list of the Kirimun Fauna is as follows (Kawamura & Nakaya, 1982; Pickford, 1982).

Mollusca
Gastropoda
Ampullariidae
Saulea lithoides
Cyclophoridae
Maizania lugubrioides
Pomatiasidae
Ligatella sp.
Enidae
? *Edouardia* sp.
Achtinidae
Burtoa cf. *nilotica*
Limicolaria sp.
Pisces
fam., gen. et sp. indet.
Reptilia
Crocodylia
Crocodylidae
gen. et sp. indet.
Testudines
Testudinidae

gen. et sp. indet.
Pelomedusidae
gen. et sp. indet.
Mammalia
Rodentia
Thryonomyidae
Paraphiomys cf. *pigotti*
Paraphiomys sp.
Pedetidae
? *Megapedetes* sp.
Cricetodontidae
Afrocricetodon sp.
Carnivora
fam., gen. et sp. indet.
Proboscidea
Gomphotheriidae
gen. et sp. indet.
Deinotheriidae
? *Prodeinotherium* sp.
Hyracoidea
Procaviidae
gen. et sp. indet.
Perissodactyla
Rhinocerotidae
Brachypotherium heinzelini
Artiodactyla
Sanitheriidae
Sanitherium sp.
Tragulidae
Dorcatherium cf. *pigotti*
Dorcatherium sp.

(10) Ombo (Kenya)

The age of this fauna was determined as Faunal Set III by faunal assemblages and this fauna must have inhabited in lake margin, swamp, large river system in volcanic arena deduced from sedimentological evidence (Bishop, 1967; Pickford, 1981). Faunal list of the Ombo Fauna is as follows (Bishop, 1967).

Mammalia
Primates
? *Mesopithecus* sp.
Creodonta
Hyaenodon sp.
Hyaenodon andrewsi
Pterodon nyanzae
Hyoboops (Merycops) africanus
Proboscidea

Gomphotherium sp.
Deinotherium sp.
Perissodactyla
Rhinocerotidae
Artiodactyla
Suidae
Dorcatherium pigotti
Tragulidae

(11) Maboko (Kenya)

The age of this fauna was determined as 12.5 Ma by K-Ar dating and as Faunal Set III by faunal assemblages (Pickford, 1981). This fauna must have inhabited in dry and wet part of floodplain in volcanic arena deduced from sedimentological evidence (Pickford, 1981). Faunal list of the Maboko Fauna is as follows (Bishop, 1967).

Mammalia
Primates
Proconsul nyanzae
Kenyapithecus africanus
? *Mesopithecus* sp.
Anasinopa leakeyi
Hyracoidea
Megalohyrax championi
Proboscidea
Gomphotherium sp.
Deinotherium sp.
Perissodactyla
Rhinocerotidae
Artiodactyla
Suidae
Tragulidae
Dorcatherium pigotti
Dorcatherium chappuisi
Dorcatherium parvum
Brachyodus aequatorialis

(12) Aka Aiteputh (Kenya)

The age of this fauna was determined as 11.5-15 Ma by K-Ar dating and as Faunal Set III by faunal assemblages (Pickford & Kuga, in press). However, radiometric age indicate Faunal Set IV. Richness of Primates indicates woodland fauna. Faunal list of the Aka Aiteputh Fauna is shown in the previous chapter (p. 8-9).

(13) Fort Ternan (Kenya)

The age of this fauna was determined as 12.5-14 Ma by K-Ar dating and as Faunal Set IV by faunal assemblages (Pickford, 1981). Faunal list of the Fort Ternan Fauna is as follows (Bishop, 1967; Pickford, 1981).

Mammalia

Primates
Kenyapithecus wickeri
? *Proconsul nyanzae*
Cercopithecidae
Rodentia
Kenyamys leakeyi
Carnivora
Proboscidea
Gomphotheriidae
Artiodactyla
Ruminants
Suidae
Giraffidae
Hippopotamidae
Kenyapotamus ternani

(14) Ngorora (Kenya)

The age of this fauna was determined as 10.2-12.7 Ma by K-Ar dating and stratigraphic position (Chapman & Brook, 1978; Pickford, 1978a; Hill et al., 1985). This fauna represents Faunal Set V of the East Africa (Pickford, 1981). Faunal list of the Ngorora A-D Formation is as follows (Benefit & Pickford, 1986).

Mammalia
Primates
Hominoidea large sp.
Hominoidea small sp.
Cercopithecoidea indet.
Carnivora
Agnotherium sp.
Eomellivora sp.
Sivaonyx sp.
Percrocuta tobieni
Canidae small sp.
Tubulidentata
Orycteropus chemeldoi
Proboscidea
Choerolophodon ngorora
Tetralophodon sp.
Deinotherium sp. cf. *bozasi*
Hyracoidea
Parapliohyrax sp.
Perissodactyla
Chilotheridium pattersoni
Aceratherium or *Dicerorhinus*
Brachypotherium cf. *lewisi*
Artiodactyla
? *Conohyus* sp.

Lopholistriodon kidogosana
Tayassuidae
Kenyapotamus coryndoni
Tragulidae
Dorcatherium cf. *pigotti*
Palaeotragus primaevus
? *Samotherium* sp.
Climacoceras gentryi
Protragocerus labidotus
Sivoreas eremita
Homoidorcas tugenium
? *Antidorcas* sp.
Pseudotragus ? *gentryi*
Pachytragus aff. *solignaci*

(15) Ngorora upper E (Kenya)

The age of this fauna was determined as Faunal Set VI by faunal assemblages. Faunal list of the Ngorora upper E Formation is as follows (Benefit & Pickford, 1986).

Mammalia
Proboscidea
Choerolophodon ngorora
Hyracoidea
Parapliohyrax sp.
Perissodactyla
Hipparion primigenium
Artiodactyla
Kenyapotamus coryndoni
Palaeotragus primaevus
Pseudotragus ? *gentryi*

(16) Ngeringerowa (Kenya)

The age of this fauna was determined as Faunal Set VI by faunal assemblages (Benefit & Pickford, 1986). Faunal list of the Ngeringerowa Fauna is as follows (Benefit & Pickford, 1986).

Mammalia
Primates
Microcolobus tugenensis
Proboscidea
Deinotherium sp. cf. *bozasi*
Perissodactyla
Hipparion primigenium
Artiodactyla
Nyanzachoerus sp.
Kenyapotamus coryndoni
Palaeotragus primaevus
? Hippotraginae or ? Reduncini

? *Antidorcas* sp.

(17) Nakali (Kenya)

The age of this fauna was determined as late Vallesian by correlation with Mediterranean mammalian fauna (Aguirre & Leakey, 1974; Aguirre & Guérin, 1974) and as Faunal Set VI by faunal assemblages (Benefit & Pickford, 1986). Nakali fauna is the nearest site of Namurungule fauna. Faunal list of the Nakali Formation is as follows (Benefit & Pickford, 1986).

Mammalia
Primates
Colobinae sp.
Proboscidea
? *Choerolophodon ngorora*
Deinotherium sp. cf. *bozasi*
Perissodactyla
Hipparion primigenium
Kenyatherium bishopi
Artiodactyla
Nyanzachoerus sp.
Kenyapotamus sp.
Tragulidae
Dorcatherium cf. *pigotti*
? *Palaeotragus primaevus*
? Hippotraginae or ? Reduncini

(18) Namurungule (Kenya)

The age of this fauna was determined as 7-10 Ma by K-Ar dating and stratigraphy and as the Turolian Fauna by faunal assemblages. Richness of equid and bovid taxa indicates openland fauna (Nakaya et al., 1984, in press). Faunal list of the Namurungule Formation is shown in the previous chapter (p. 9-11).

(19) Chorora (Middle Awash, Ethiopia)

The age of this fauna was determined as 9-10.5 Ma by radiometric dating. Faunal list of the Chorora Formation is as follows (Jacobs et al., 1980; Kalb et al., 1982a, 1982b, 1982c).

Mammalia
Rodentia
cf. Dendromurinae
Paraulacodus johanesi
Paraphiomys sp. 1
Paraphiomys sp. 2
Rodentia gen. et sp. indet.
Carnivora
Homotherium sp.
Proboscidea
Gomphotheriinae indet.

Perissodactyla
Hipparion cf. *primigenium*
Dicerorhinus (*Stephanorhinus*) aff. *leakeyi*
Artiodactyla
Suidae gen. et sp. indet.
? Palaeotraginae
Bovidae gen. et sp. indet.

(20) Mpesida (Kenya)

The age of this fauna was determined as about 7 Ma. and as Faunal Set VII by faunal assemblages (Benefit & Pickford, 1986). Faunal list of the Mpesida Formation is as follows (Gentry, 1978a).

Mammalia
Artiodactyla
Tragelaphini
Antilopini
? Alcelaphini
Bovidae indet.

(21) Lukeino (Kenya)

The age of the Member A of Lukeino Formation was determined as about 6.0-6.7 Ma and as Faunal Set VII by faunal assemblages (Benefit & Pickford, 1986). This fauna must have inhabited in lacustrine environments deduced from sedimentological evidence. Faunal list of the Member A and B of the Lukeino Formation is as follows (Pickford, 1978 b; Gentry, 1978a).

Mammalia
Primates
Cercopithecidae
Hominidae
Lagomorpha
gen. et sp. indet.
Rodentia
Hystrix sp.
gen. et sp. indet.
Carnivora
Enhydriodon
cf. *Ichneumia* sp.
cf. *Crocuta*
Felidae gen. et sp. indet.
Tubulidentata
Orycteropus sp.
Proboscidea
Anancus sp.
Stegotetrabelodon sp.
Primelephas sp.
Deinotherium sp.

Hipparion cf. *sitifense*
Chalicotheriidae
cf. *Ceratotherium* sp.
Nyanzachoerus tulotos
Hippopotamus sp.
Giraffa sp.
Tragelaphini
Reduncini
Hippotragini
Neotragini
Antilopini cf. *Aepyceros*
Gazella sp.
Cephalophini
Alcelaphini

(22) Lothagam 1 (Kenya)

The age of this fauna was determined as before 3.7 Ma by K-Ar dating and stratigraphy and as Faunal Set VII by faunal assemblages (Benefit & Pickford, 1986). This fauna must have inhabited in fluvial environments deduced from sedimentological evidence (Behrensmeyer, 1976). Faunal list of the Lothagam 1 Formation is as follows (Smart, 1976).

Mammalia
Primates
cf.*Parapapio* sp.
cf.*Cercocebus* sp.
Australopithecus sp. cf. *africanus*
Rodentia
Anomaluridae (non gliding form)
Carnivora
Civettictis sp.
Euryboas sp.
Felinae (large primitive form)
Machairodontinae
Tubulidentata
Leptorycteropus guilielmi
Proboscidea
Anancinae (primitive form)
Primelephas gomphotheroides
Stegotetrabelodon orbus
Deinotherium sp.
Perissodactyla
Hipparion primigenium
Hipparion sitifense (pygmy form)
Hipparion turkanense
Brachypotherium lewisi
Ceratotherium praecox

Artiodactyla
Nyanzachoerus tulotos
Nyanzachoerus aff. *jaegeri*
Hippopotamus (*Hexaprotodon*) sp. A
Hippopotamus (*Hexaprotodon*) sp. B (pygmy form)
Giraffa sp.
Pachytragus aff. Hippotraginae
aff. *Kobus* sp.
aff. *Redunca* sp.
aff. *Aepyceros* sp.
aff. *Damaliscus* sp.
Hippotragini
Miotragocerus sp.
Tragelaphus sp. A
Tragelaphus sp. B
Gazella sp. A (large form)
Gazella sp. B (small form)
Antilope sp.
Neotragini aff. *Rhynchotragus* sp.

(23) Adu-Asa (Middle Awash, Ethiopia)

The age of this fauna was determined as the latest Miocene to earliest Pliocene by radiometric age and stratigraphy (Kalb et al., 1982a). Faunal list of the Adu-Asa Formation is as follows (Kalb et al., 1982a, 1982b, 1982c).

Mammalia
Chiroptera indet.
Primates
cf. *Paracolobus chemeroni*
Colobinae indet. (Kuseralee type)
Rodentia gen. et sp. indet.
Carnivora
Felidae gen. et sp. indet.
Hyaenidae gen. et sp. indet.
Carnivora gen. et sp. indet.
Proboscidea
Anancus sp. A (cf. Lothagam type)
Anancus sp. B (cf. *kenyensis*)
Stegotetrabelodon cf. *orbus*
"*Stegodibelodon* " *schneideri*
Primelephas cf. *gomphotheroides*
aff. "*Mammuthus subplanifrons* "
Deinotherium sp. (small)
Perissodactyla
Hipparion cf. *primigenium*
Hipparion sp.
Diceros bicornis

Ceratotherium cf. *praecox*
Artiodactyla
Nyanzachoerus kanamensis
Nyanzachoerus cf. *tulotos*
Kolpochoerus sp. A
Hexaprotodon sp. (large)
Sivatherium maurusium
Giraffidae gen. et sp. indet.
Miotragocerus sp.
Kobus cf. *subdolus*
Tragelaphus sp. (cf. Lothagam type)
Tragelaphus aff.*nakuae*
cf. *Gazella* sp.
cf. *Ugandax gautieri*.
cf. *Mesembriportax acrae*
Boselaphini indet.
Reduncini indet.
Hippotragini indet.
Alcelaphini indet.
Bovidae indet.

(24) Sagantole (Middle Awash, Ethiopia)

The age of this fauna was determined as the early Pliocene by radiometric age and stratigraphy (Kalb et al., 1982a). Faunal list of the Sagantole Formation is as follows (Kalb et al., 1982a, 1982b, 1982c)

Mammalia
Primates
Cercopithecus sp.
cf. Papionini indet.(small)
Parapapio sp.
Theropithecus oswaldi cf. *darti*
Rodentia gen. et sp. indet.
Carnivora indet.
Proboscidea
Anancus sp. B (cf. *kenyensis*)
Anancus sp. C (aff. *kenyensis*)
Anancus sp. D (sp. nov.)
Mammuthus subplanifrons
Mammuthus sp. nov. (Hadar type)
Elephas cf. *ekorensis*
Loxodonta adaurora
Deinotherium bozasi
Perissodactyla
Hipparion sp.
Rhinocerotidae gen. et sp. indet.
Artiodactyla

Nyanzachoerus kanamensis
Nyanzachoerus jaegeri
Kolpochoerus afarensis
Notochoerus cf. *euilus*
Hexaprotodon sp. (large)
Sivatherium maurusium
Miotragocerus sp.
Kobus cf. *subdolus*
Tragelaphus aff.*nakuae*
Boselaphini indet.
Hippotragini indet.
Alcelaphini indet.
Bovidae indet.

(25) Ekora (Kenya)

The age of this fauna was determined as 2.5-4 Ma by K-Ar dating. Faunal list of the Ekora Formation is as follows (Behrensmeyer, 1976).

Mammalia
Proboscidea
Anancus sp.
Elephas ekorensis
Loxodonta adaurora
Perissodactyla
Ceratotherium praecox
Artiodactyla
Nyanzachoerus cf. *plicatus*

(26) Kanapoi (Kenya)

The age of this fauna was determined as 2.5-4 Ma by K-Ar dating. This fauna must have inhabited in transitional (littoral, deltaic) environments deduced from sedimentological evidence. Faunal list of the Kanapoi Formation is as follows (Behrensmeyer, 1976).

Mammalia
Primates
Parapapio jonesi
cf. *Australopithecus*
Lagomorpha
Lepus sp.
Rodentia
Hystrix sp.
Tatera sp.
Carnivora
Enhydriodon sp. nov.
Hyaena sp.
Machairodontinae indet.
Proboscidea

Anancus sp.
Elephas ekorensis
Loxodonta adaurora
Deinotherium bozasi
Perissodactyla
Hipparion primigenium
Ceratotherium praecox
Artiodactyla
Nyanzachoerus pattersoni
Nyanzachoerus plicatus
Nyanzachoerus spp.
Notochoerus cf. *capensis*
Notochoerus cf. *euilus*
Hippopotamus sp. nov.
Giraffa sp. nov.
Giraffa sp.
Tragelaphus sp.
Reduncini sp.

(27) Lothagam 3 (Kenya)

The age of this fauna was determined as after 3.7 Ma by K-Ar dating and stratigraphy and as Faunal Set VIII by faunal assemblages (Benefit & Pickford, 1986). This fauna must have inhabited in fluvial environments deduced from sedimentological evidence. Faunal list of the Lothagam 3 Formation is as follows (Behrensmeyer, 1976).

Mammalia
Primates
Simopithecus sp.
Proboscidea
Loxodonta adaurora
Deinotherium bozasi
Perissodactyla
Hipparion (*Stylohipparion*) sp.
Artiodactyla
Nyanzachoerus plicatus
Notochoerus cf. *euilus*
Hippopotamidae indet.
Tragelaphus sp.
Bovidae indet.

(28) Laetoli (Tanzania)

The age of this fauna was determined as 3.49-4.32 Ma by K-Ar dating (Drake & Curtis, 1987). In the upper Laetoli Beds, grass pollen predominates (50-80%) over that of the composite. This palynological evidence indicates short or medium grassland (Bonnefille et al., 1987). Faunal list of the Laetoli Bed is as follows (Leakey & Harris eds., 1987).

Reptilia
  Testudinidae
    Geochelone (Aldabrachelys) laetoliensis
    Geochelone (Geochelone) brachygularis
  Serpentes
  Boidae
    Python sebae
  Colubridae
    cf. *Rhamphiophis* sp.
  Elapidae
    Naja robusta
  Viperidae
    Bitis arietans or *olduvaiensis*
Aves
  Falconiformes
    Torgos sp.
  Galiformes
    Francolinus spp.
    Numida sp.
  Columbiformes
    Streptopelia sp.
  Strigiformes
    Bubo sp.
Mammalia
Macroscelidea
  Macroscelididae
    Rhynchocyon pliocaenicus
Insectivora
  Soricidae
    ? *Crocidura* sp.
Primates
  Lorisidae
    Galago sadimanensis
  Cercopithecidae
    Parapapio ado
    cf. *Papio* sp.
    cf. *Paracolobus* sp.
    Colobinae gen. et sp. indet.
  Hominidae
    Australopithecus afarensis
Rodentia
  Sciuridae
    Paraxerus sp.
    Xerus sp.
    Xerus cf. *janenschi*
  Cricetidae
    Gerbillinae gen. et sp. indet.

Tatera cf. *inclusa*
Dendromus sp.
Steatomys sp.
Saccostomus major
Muridae
Thallomys laetolilensis
Mastomys cinereus
Muridae gen. et sp. indet.
Bathyergidae
Heterocephalus quenstedti
Hystricidae
Hystrix leakeyi
Hystrix cf. *makapanensis*
Xenohystrix crassidens
Lagomorpha
Pedetidae
Pedetes laetoliensis
Pedetes cf. *surdaster*
Leporidae
Serengetilagus praecapensis
Carnivora
Viverridae
Herpestes (Galerella) palaeoserengetensis
Herpestes (Herpestes) ichneumon
Helogale palaeogracilis
? *Cynictis* sp.
Mungos dietrichi
Viverra leakeyi
Mustelidae
Propoecilogale bolti
Mellivora capensis
Canidae
? *Megacyon* sp.
aff. *Canis brevirostris*
Vulpes sp.
cf. *Otocyon* sp.
Canidae gen. et sp. indet.
Hyaenidae
Crocuta sp. nov.
Hyaenidae spp.
Felidae
Homotherium sp.
Dinofelis sp.
Leo aff. *gombazoegensis* or *palaeosinensis*
Leo cf. *pardus*
Felis spp.
Felidae gen. et sp. indet.

Proboscidea
  Elephantidae
    Loxodonta exoptata
  Deinotheriidae
    Deinotherium bozasi
Tubulidentata
  Orycteropodidae
    Orycteropus sp.
Perissodactyla
  Equidae
    Hipparion cf. *ethiopicum*
    Hipparion sp.
  Chalicotheriidae
    Ancylotherium hennigi
  Rhinocerotidae
    Cetatotherium praecox
    Diceros bocornis
Artiodactyla
  Suidae
    Notochoerus euilus
    Potamochoerus porcus
    Kolpochoerus limnetes
  Giraffidae
    Giraffa stillei
    Giraffa jumae
    Giraffa cf. *jumae*
    Sivatherium maurusium
    Sivatherium cf. *maurusium*
  Camelidae
    Camelus sp.
  Bovidae
  Tragelaphini
    Tragelaphus sp.
  Bovini
    Simatherium kohllarseni
    Brabovus nanincisus
  Hippotragini
    Praedamalis deturi
    ? Hippotragini sp. nov.
  Alcelaphini
    Parmularius pandatus
    Alcelaphini sp. indet.
  Neotragini
    Madoqua aviffuminis
    ? *Raphicerus* sp.
  Antilopini
    Gazella janenschi

Tribe et gen. indet. aff. *Pelea* sp.
Bovidae indet.

(29) Langebaanweg (South Africa)

The age of the Verswater Formation in 'E' Quarry, Langebaanweg was determined as 4-6 Ma by faunal assemblage and stratigraphy. Marine to Littoral (Bed 1), Estuarine and Terrestrial (Bed 2) and Estuarine (Bed 3) environments were shown by sedimentological evidence. Marine invertebrates and shark teeth were yielded in the phosphate of the Bed 1. This fauna must have inhabited in Marine (Bed 1) and Estuarine (Bed 2 and 3) Faunal Units (Hendey, 1974). Faunal list of the Varswater Formation is as follows (Boné & Singer, 1965; Hendey, 1974; Gentry, 1980).

Mollusca
Trigonephrus sp.
Selachii
Isurus cf. *glaucus*
Lamna nasus
Carcharias sp.
Carcharias ferox
Rhinoptera cf. *dubia*
Glopias vulpes
Reptilia
cf. *Testudo* sp.
Aves
cf. *Struthio* sp.
Mammalia
Insectivora
Elephantulus sp.
Soricidae spp.
Chrysochloris sp.
Primates
cf. Cercopithecidae
Rodentia
Muridae spp.
Bathyergidae spp.
Lagomorpha
gen. et sp. indet.
Pholidota
cf. *Manis* sp.
Tubulidentata
Orycteropus sp.
Carnivora
Phocidae
Prionodelphis capensis
Ursidae
Agriotherium africanum
Viverridae

Herpestes spp.
Viverra leakeyi
Genetta sp.
Mustelidae
Mellivora aff. *punjabiensis*
Enhydriodon africanus
Canidae
Canidae gen. et sp. indet.
Hyaenidae
Percrocuta australis
Hyaena abronia
Hyaena sp. B
Hyaenictis preforfex
Hyaenidae gen. et sp. indet.
Felidae
Machairodus sp.
cf. *Homotherium* sp.
Dinofelis diastemata
Felis aff. *issiodorensis*
Felis obscura
Cetacea
fam. gen. et sp. indet.
Hyracoidea
cf. *Procavia antiqua*
Proboscidea
Gomphotheriidae
Elephantidae
Mammuthus subplanifrons
Perissodactyla
Equidae
Hipparion albertense baardi
Rhinocerotidae
Cetatotherium praecox
Artiodactyla
Suidae
Nyanzachoerus sp.
aff. *Diamantohyus*
Libytherium oldvaiense
Giraffidae
Giraffa gracilis
Bovidae
Tragelaphini
Tragelaphus spp.
Bovini
Simatherium demissum
Boselaphini
Mesembriportax acrae

Reduncini
Kobus subdolus
Kobus spp.
Alcelaphini
Damalacra neanica
Damalacra acalla
Neotragini
Raphicerus partalius
Antilopini
Gazella sp.
Ovibovini gen. et sp. indet.

Large Mammal Faunal Range Chart of Neogene East Africa is compiled mainly from Pickford (1981), Pickford et al. (1984), Benefit & Pickford (1986), Nakaya (1987, 1989, 1993) and Nakaya et al. (1984, in press) in the next chapter (Table 7). Many taxa of Neogene Sub-Saharan Africa are represented by incomplete fossil remains. Identification of some species from East Africa are problematic. Therefore, in the next chapter, I use specific names for complete or distinguished remains and generic, genus group, and tribal names for incomplete materials from the Neogene Sub-Saharan Africa.

DISCUSSION

I. Statistical Analysis of Faunal Resemblance between Sub-Saharan Africa and Eurasia

The faunal resemblance of mammalian faunas of Sub-Saharan Africa and Eurasia is analyzed in this chapter.

Mammal provinces of Miocene Africa and Eurasia were divided into five areas (Africa, Iberian, Europe, West Asia and India) by Coryndon & Savage (1973) and Bernor (1983, 1984) proposed eight provinces (Southwest Europe, East and Central Europe, Roumania-West C.I.S., Sub-Paratethys, North Africa, Siwalik, East Africa and China). In this work, mammalian provinces are followed largely the scheme of Bernor (1983, 1984). East African province (Bernor, 1983, 1984) is the same as Sub-Saharan, and Roumania-West C.I.S. (Bernor, 1983, 1984) province is included in Sub-Paratethys in this work.

Previous researchers emphasized the Miocene faunal connection between Sub-Saharan Africa and Siwaliks (general: Coryndon & Savage, 1973; Bovidae: Thomas, 1979, 1981; Hipparionine: Bernor & Hussain, 1985). However, it has been pointed out that the discussion of connection between Sub-Saharan Africa and Siwaliks is based largely on fragmental remains from the middle to late Miocene Sub-Saharan sites. The following discussion of the biogeography between Sub-Saharan and Eurasia is based on new and rich mammalian fossils from the late Miocene Namurungule Formation, Samburu Hills, Northern Kenya.

Statistical approaches are very useful for analyzing the resemblance of faunas. Simpson's formula is simple and useful for analyzing resemblance between two faunal

assemblages. This index is dividing the common taxa numbers by the total taxa numbers of smaller fauna. Cluster analysis is also useful for multivariant analysis between faunas of Sub-Saharan Africa and Eurasia. In this thesis, the author analyzed species, genera and families of Sub-Saharan Africa and Eurasian faunas by Simpson's Index and genera and families of the same area by cluster analysis. Because subfamily and tribe are not mainly used in classification except Rhinocerotidae (Perissodactyla) and Bovidae (Artiodactyla) in both statistic methods and common taxa are very few in the specific level for using cluster analysis.

Over 500 taxa from the following mammalian fauna are analyzed by Simpson's Index (Simpson, 1960) and cluster analysis (Tanaka et al. eds., 1984).

Namurungule (early Turolian, Samburu Hills, Kenya), Aka Aiteputh (Astaracian, Samburu Hills, Kenya), Kongia (late Turolian, Samburu Hills, Kenya), Ngorora (Vallesian, Baringo Basin, Kenya), Ngorora upper E (early Turolian, Baringo Basin, Kenya), Ngeringerowa (early Turolian, Baringo Basin, Kenya), Nakali (early Turolian , Baringo Basin, Kenya), Mpesida(late Turolian, north Baringo Basin, Kenya), Lukeino (late Turolian, north Baringo Basin, Kenya), Bou Hanifia (late Vallesian, Algeria), Sahabi (Turolian, Libya), Eppelsheim (late Vallesian, West Germany), Dorn-Dürkheim (late Turolian, West Germany), Mt.Lebéron (early Turolian, France), Pikermi (middle Turolian, Greece), Maragheh (Turolian, Iran), Samos (early to middle Turolian Greece), Chinji (Astaracian, Pakistan), Nagri (late Vallesian or early Turolian, Pakistan), Dhok Pathan (late Turolian, Pakistan), Baode (early Turolian, Shanxi, China), Yushe Zone I (late Turolian, Shanxi, China) (Table 2).

Faunal resemblance is analyzed by various statistic methods. Faunal resemblance of two faunas is calculated by the following formulas (Shuey et al., 1978).

1. Jaccard

$$\frac{C}{N_A+N_B-C}$$

2. Burt-Pilot

$$\frac{2C}{N_A+N_B}$$

3. Kulczynski

$$\frac{C(N_A+N_B)}{2N_AN_B}$$

4. Otsuka

$$\frac{C}{\sqrt{N_AN_B}}$$

5. Simpson

$$\frac{C}{N_1}$$

6.Braun-Blaunquet

$$\frac{C}{N_2}$$

C is common taxa number of two faunas, NA is total taxa number of A Fauna, NB is

total taxa number of B Fauna, N1 is total taxa number of smaller fauna, N2 is total taxa number of larger fauna.

Simpson's formula is the simplest and has little influence of sample size and emphasizes faunal resemblance (Simpson, 1960). Simpson's Index is shown on percentage:

$$\frac{C \times 100}{N_1}$$

The author examined faunal resemblance of each two faunas by Simpson's index. In the specific level, the Namurungule Fauna indicates the resemblance to the following East and North African faunas; Nakali (50%), Ngorora upper E (33.33%), Ngeringerowa (33.3%), Lukeino (33.3%), and Bou Hanifia (33.33%) (Table 4). In the generic level, the Namurungule Fauna indicates the resemblance to the following faunas of East and North Africa and Sub-Paratethys; Nakali (75%), Ngorora upper E (57.14%), Ngeringerowa (55.56%), Bou Hanifia (50%) and Samos (44.44%), Mpesida (40%) (Table 5). In the family level, the Namurungule Fauna indicates the resemblance to the following faunas of East and North Africa and Southwestern and Central Europe; Bou Hanifia (100%), Ngorora upper E (85.71%), Mt. Lebéron (83.33%), Eppelsheim (83.33%) and Mpesida (80%) (Table 6).

The reciprocal number of Simpson's index (N1/C) is used for showing the dissimilarity on the group average method of cluster analysis (by CLUST program, Tanaka et al., 1984). In the case that Simpson's index is zero, the dissimilarity is uncountable. Therefore, analysis of all faunas in the case of species and the Aka Aiteputh and Dorn-Dürkheim faunas in the case of genera are omitted from the cluster analysis. In the generic level, the Namurungule and only East African faunas make large cluster (Nakali; firstly, Ngorora upper E; secondly, Ngorora and Ngeringerowa; thirdly) (Fig. 10). The Namurungule, East and North African and west European faunas make large cluster (Bou Hanifia; firstly, Nakali, Mt. Lebéron and Sahabi; secondly) in family level (Fig. 11). Using the raw data of Sub-Saharan and Eurasian faunas, faunal resemblance of each fauna was examined by group average method in cluster analysis on the basis of dissimilarity of Minkowsky distance (by CLUST program, Tanaka et al. eds., 1984). In the generic level, the Namurungule and East (Aka Aiteputh, Kongia, Ngorora E, Ngeringerowa, Nakali, and Lukeino) and North African (Bou Hanifia) and South-Western European (Mt. Lebéron) faunas make first large cluster and Dorn-Dürkheim faunas make next large cluster (Fig. 12). In the family level, the Namurungule and Eppelsheim faunas make first cluster, Lukeino faunas make next cluster, and Kongia, Mpesida, Bou Hanifia, Mt. Lebéron, Ngorora E, Ngeringerowa, Nakali and Dhok Pathan faunas make next large cluster (Fig. 13).

The Namurungule Fauna resembles faunas of Astaracian to late Turolian East Africa firstly, late Vallesian to Turolian North African faunas secondly, late Vallesian to Turolian Central and Southwest European faunas thirdly, early to middle Turolian Sub-Paratethys fauna and late Turolian Siwalik fauna lastly. On the basis of the above results, the Namurungule Fauna indicates similarity with the faunas of North Africa, South Western Europe and Sub-Paratethys.

Table 4. Faunal resemblance of the Namurungule Fauna, African and Eurasian faunas in specific level by the Simpson's index.

	NM	AA	NG	NE	NW	NK	LK	MP	SB	BH	ML	EP	PK	SM	MG	CJ	NR	DP	BD	YS	DD
NM	NM(9)		1	2	2	2	1		2	1											
AA	0	AA(10)	2		1																
NG	11.11	20	NG(15)	4	4	2		1								1					
NE	33.33	0	66.67	NE(6)	4	4			1	1											
NW	33.33	16.67	66.67	66.67	NW(6)	3			1	1						1					
NK	50	0	50	100	75	NK(4)			1	1											
LK	33.33	0	0	0	0	0	LK(3)	1	1												
MP	0	0	50	0	0	0	50	MP(2)		1											
SB	22.22	0	0	16.67	16.67	25	33.33	0	SB(25)		1		2	2	2						1
BH	33.33	0	0	33.33	33.33	33.33	0	50	0	BH(3)											
ML	0	0	0	0	0	0	0	0	12.5	0	ML(8)		3	3	2						1
EP	0	0	0	0	0	0	0	0	0	0	0	EP(22)	3	3							2
PK	0	0	0	0	0	0	0	0	8	0	37.5	13.64	PK(64)	42	19						3
SM	0	0	0	0	0	0	0	0	8	0	37.5	13.64	65.63	SM(82)	26				2	1	2
MG	0	0	0	0	0	0	0	0	8	0	25	0	48.72	66.67	MG(39)				1		1
CJ	0	0	6.667	0	16.67	0	0	0	0	0	0	0	0	0	0	CJ(44)					
NR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NR(59)				
DP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	DP(22)			
BD	0	0	0	0	0	0	0	0	0	0	0	0	0	3.333	2.564	0	0	0	BD(60)	14	
YS	0	0	0	0	0	0	0	0	0	0	0	0	0	2.222	0	0	0	0	31.11	YS(45)	
DD	0	0	0	0	0	0	0	0	4.762	0	12.5	9.524	14.29	9.524	4.762	0	0	0	0	0	DD(21)

Note: NM; Namurungule, AA; Aka Aiteputh, KG; Kongia, NG; Ngorora, NE; Ngorora upper E, NW; Ngeringerowa, NK; Nakali, LK; Lukeino, MP; Mpesida, SB; Sahabi, BH; Bou Hanifia, ML; Mt. Lebéron, EP; Eppelsheim, PK; Pikermi, SM; Samos, MG; Maragheh, CJ; Chinji, NR; Nagri, DP; Dhok Pathan, BD; Baode, YS; Yushe, DD; Dorn-Dürkheim. Total number of taxa is put in parentheses.

Table 5. Faunal resemblance of the Namurungule Fauna, African and Eurasian faunas in generic level by the Simpson's index.

	NM	AA	NG	NE	NW	NK	LK	MP	SB	BH	ML	EP	PK	SM	MG	CJ	NR	DP	BD	YS	DD
NM	NM(18)	1	6	4	5	6	4	2	5	2	2	4	7	8	7	3	4	2	6	5	3
AA	8.333	AA(12)	3		1							1		1		1	1	1			
NG	33.33	25	NG(28)	5	7	3	1	2	2	1	3	5	7	10	6	9	9	3	5	6	1
NE	57.14	0	71.43	NE(7)	4	5	2	1	1	1	1	2	4	5	3	2	3	1	2	2	1
NW	55.56	11.11	77.78	57.14	NW(9)	5	3	1	2	2	2	3	6	7	4	3	3	2	2	3	1
NK	75	0	37.5	71.43	62.5	NK(8)	3	1	2	2	2	2	5	5	4	1	3	2	2	2	1
LK	26.67	0	6.667	28.57	33.33	37.5	LK(15)	3	4	1	1	2	5	6	3	3	4	3	2	3	1
MP	40	0	40	20	20	20	60	MP(5)	3	1	1	2	2	2	1	2	2	2	1	1	
SB	27.78	0	7.143	14.29	22.22	25	26.67	60	SB(34)	2	5	3	10	10	10	5	5	3	3	1	2
BH	50	0	25	25	50	50	25	25	50	BH(4)	3	2	3	3	2	2	2	1	3	2	
ML	20	0	30	14.29	22.22	25	10	20	50	75	ML(10)	5	6	5	4	4	3	2	2	2	2
EP	22.22	8.333	27.78	28.57	33.33	25	13.33	40	16.67	50	50	EP(18)	7	5	2	9	9	5	3	4	3
PK	38.89	0	25	57.14	66.67	62.5	33.33	40	29.41	75	60	38.89	PK(56)	37	22	10	9	5	11	11	6
SM	44.44	8.333	35.71	71.43	77.78	62.5	40	40	29.41	75	50	27.78	66.07	SM(58)	26	10	13	7	14	10	6
MG	38.89	0	21.43	42.86	44.44	50	20	20	29.41	50	40	11.11	64.71	76.47	MG(34)	6	6	3	11	7	3
CJ	16.67	8.333	32.14	28.57	33.33	12.5	20	40	14.71	50	40	50	20	20	17.65	CJ(50)	30	12	5	4	
NR	22.22	8.333	32.14	42.86	33.33	37.5	26.67	40	14.71	50	30	50	16.07	22.41	17.65	60	NR(62)	19	7	7	2
DP	11.11	8.333	14.29	14.29	22.22	25	20	40	14.29	25	20	27.78	23.81	33.33	14.29	57.14	90.48	DP(21)	5	4	
BD	33.33	0	17.86	28.57	22.22	25	13.33	20	8.824	75	20	16.67	31.43	40	32.35	14.29	20	23.81	BD(35)	18	3
YS	27.78	0	21.43	28.57	33.33	25	20	20	2.941	50	20	22.22	32.35	29.41	20.59	11.76	20.59	19.05	52.94	YS(34)	2
DD	16.67	0	3.704	14.29	11.11	12.5	6.667	0	7.407	0	20	16.67	22.22	22.22	11.11	0	7.407	0	11.11	7.407	DD(27)

Note: NM; Namurungule, AA; Aka Aiteputh, KG; Kongia, NG; Ngorora, NE; Ngorora upper E, NW; Ngeringerowa, NK; Nakali, LK; Lukeino, MP; Mpesida, SB; Sahabi, BH; Bou Hanifia, ML; Mt. Lebéron, EP; Eppelsheim, PK; Pikermi, SM; Samos, MG; Maragheh, CJ; Chinji, NR; Nagri, DP; Dhok Pathan, BD; Baode, YS; Yushe, DD; Dorn-Dürkheim. Total number of taxa is put in parentheses.

Table 6. Faunal resemblance of the Namurungule Fauna, African and Eurasian faunas in family level by the Simpson's index.

	NM	AA	NG	NE	NW	NK	LK	MP	SB	BH	ML	EP	PK	SM	MG	CJ	NR	DP	BD	YS	DD
NM	NM(15)	7	10	6	6	10	11	4	11	5	5	10	10	10	9	10	10	7	8	8	3
AA	58.33	AA(12)	10	4	4	6	5	1	5	2	2	6	6	7	4	6	7	5	4	4	2
NG	66.67	83.33	NG(18)	6	7	11	12	3	10	4	4	8	11	12	10	10	12	12	12	13	4
NE	85.71	57.14	85.71	NE(7)	5	6	5	3	5	2	1	3	6	6	4	4	4	4	4	4	2
NW	75	50	87.5	71.43	NW(8)	7	6	3	6	3	2	4	6	6	5	5	5	6	4	4	1
NK	76.92	50	84.62	85.71	87.5	NK(13)	10	4	10	5	6	7	10	9	9	9	9	8	8	8	3
LK	73.33	41.67	66.67	71.43	75	76.92	LK(18)	5	12	5	6	9	11	11	10	12	13	9	7	7	4
MP	80	20	60	60	60	80	100	MP(5)	5	3	2	2	5	5	3	4	3	4	3	3	
SB	73.33	41.67	55.56	71.43	75	76.92	66.67	100	SB(24)	5	6	8	13	13	11	12	12	8	9	10	6
BH	100	40	80	40	60	100	100	60	100	BH(5)	4	4	5	5	5	5	5	5	5	5	1
ML	83.33	33.33	66.67	16.67	33.33	100	100	40	100	80	ML(6)	5	5	5	5	6	6	4	5	5	2
EP	83.33	50	66.67	42.86	50	58.33	75	40	66.67	80	83.33	EP(12)	10	10	8	10	11	7	7	7	8
PK	66.67	50	61.11	85.71	75	76.92	61.11	100	54.17	100	83.33	83.33	PK(25)	19	14	13	13	9	7	13	8
SM	66.67	58.33	66.67	85.71	75	69.23	61.11	100	54.17	100	83.33	83.33	79.17	SM(24)	15	15	13	9	11	12	8
MG	60	33.33	66.67	57.14	62.5	69.23	66.67	60	73.33	100	83.33	66.67	93.33	100	MG(15)	10	11	7	11	11	5
CJ	66.67	50	55.56	57.14	62.5	69.23	66.67	80	60	100	100	83.33	65	75	66.67	CJ(20)	18	11	8	8	7
NR	66.67	58.33	66.67	57.14	62.5	69.23	72.22	60	50	100	100	91.67	52	54.17	73.33	90	NR(25)	10	8	8	8
DP	58.33	41.67	100	57.14	75	66.67	75	80	66.67	100	66.67	58.33	75	75	58.33	91.67	83.33	DP(12)	6	6	3
BD	66.67	33.33	100	57.14	50	66.67	58.33	60	75	100	83.33	58.33	58.33	91.67	91.67	66.67	66.67	50	BD(12)	12	5
YS	53.33	33.33	86.67	57.14	50	61.54	46.67	60	66.67	100	83.33	58.33	86.67	80	73.33	53.33	53.33	50	100	YS(15)	6
DD	30	20	40	28.57	12.5	30	40	0	60	20	33.33	80	80	80	50	70	80	30	50	60	DD(10)

Note: NM; Namurungule, AA; Aka Aiteputh, KG; Kongia, NG; Ngorora, NE; Ngorora upper E, NW; Ngeringerowa, NK; Nakali, LK; Lukeino, MP; Mpesida, SB; Sahabi, BH; Bou Hanifia, ML; Mt. Lebéron, EP; Eppelsheim, PK; Pikermi, SM; Samos, MG; Maragheh, CJ; Chinji, NR; Nagri, DP; Dhok Pathan, BD; Baode, YS; Yushe, DD; Dorn-Dürkheim. Total number of taxa is put in parentheses.

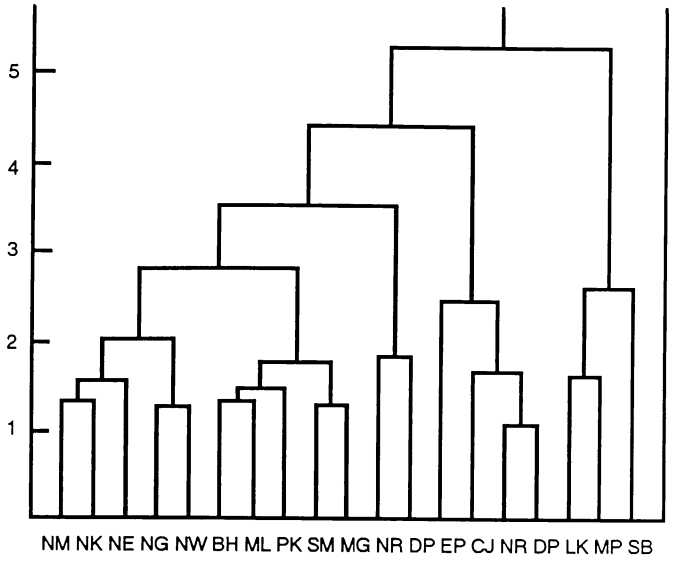


Fig. 10. Dendrogram by the cluster analysis on the basis of the faunal dissimilarity of the Namurungule Fauna, African and Eurasian faunas (in generic level by the reciprocal number of Simpson's index).
AA: Aka Aiteputh; BD: Baode; BH: Bou Hanifia; CJ: Chinji; DD: Dorn- Dürkheim; DP: Dhok Pathan; EP: Eppelsheim; NB: Kongia; LK: Lukeino; MG: Maragheh; ML: Mt. Lebéron; MP: Mpesida; NE: Ngorora upper E; NG: Ngorora; NK: Nakali; NM: Namurungule; NW: Ngeringerowa; PK: Pikermi; SB: Sahabi; SM: Samos; YS: Yushe.

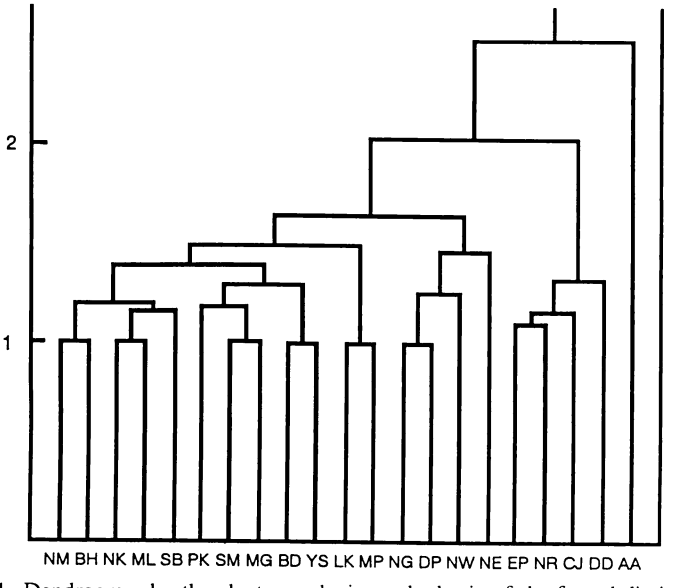


Fig. 11. Dendrogram by the cluster analysis on the basis of the faunal dissimilarity of the Namurungule Fauna, African and Eurasian faunas (in family level by the reciprocal number of Simpson's index).

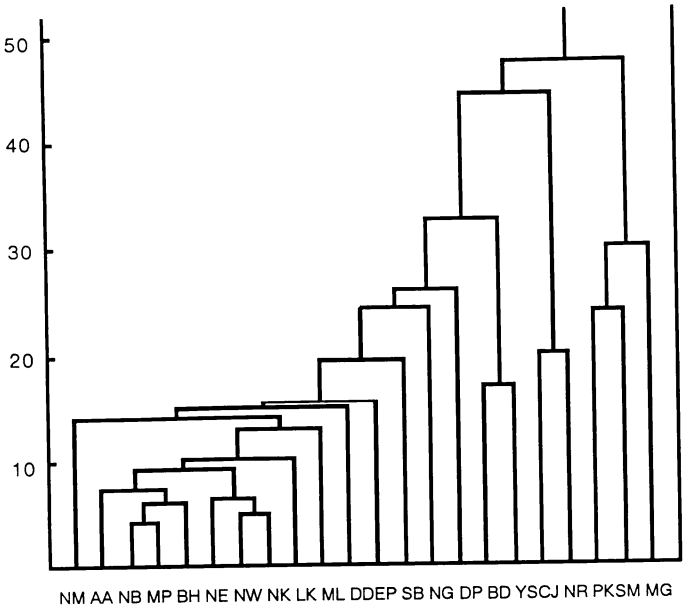


Fig. 12. Dendrogram by the cluster analysis on the basis of taxa of the typical Astaracian to Turolian African and Eurasian faunas (in generic level by Minkowsky's distance).

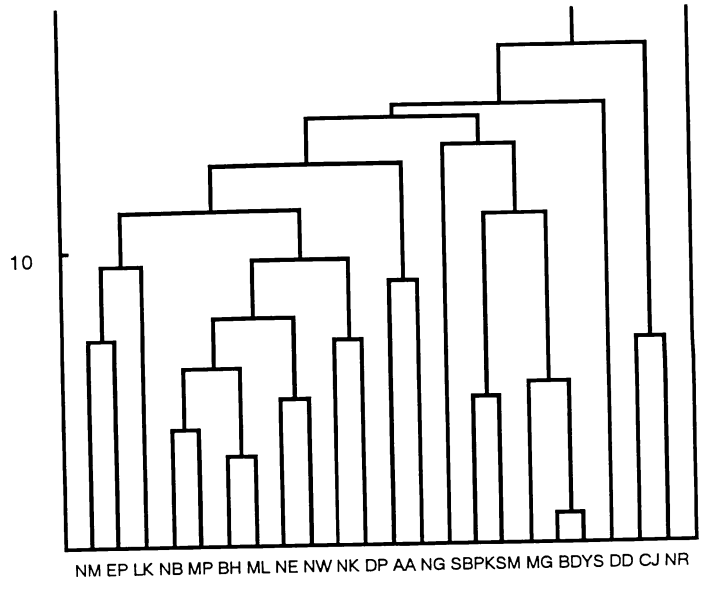
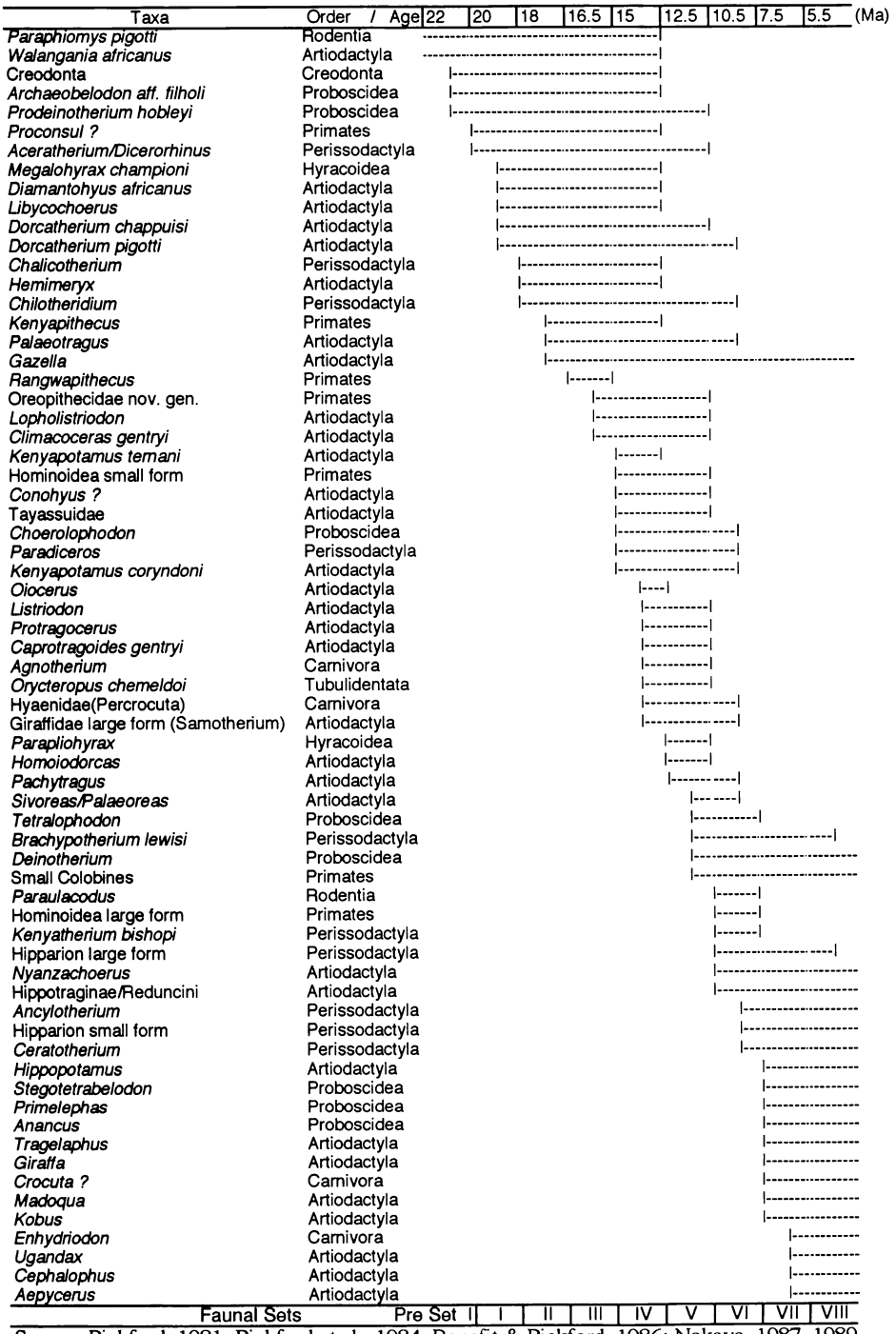


Fig. 13. Dendrogram by the cluster analysis on the basis of taxa of the typical Astaracian to Turolian African and Eurasian faunas (in family level by Minkowsky's distance).

Table 7. Range chart of mammalian faunas from the Neogene Sub-Saharan Africa.



Source: Pickford, 1981; Pickford et al., 1984; Benefit & Pickford, 1986; Nakaya, 1987, 1989, 1993; Nakaya et al., in press.

II. Faunal Change of the Late Miocene Sub-Saharan Africa

In this chapter, the author analyzes faunal change of the Neogene mammalian faunas in Sub-Saharan Africa and establishes the position of the faunal turnover in Neogene Sub-Saharan Africa to the Namurungule Fauna.

In faunal change of late Miocene East Africa, Maglio (1978) reviewed patterns of faunal evolution of Africa. According to Maglio (1978), the rate of endemism is constant through the Cenozoic Era, the rate of turn over has two peaks (from Eocene to early Miocene and Pliocene) in the Cenozoic Era and the rate of extinction decreased constantly by genera through Neogene in the Africa. Savage & Russell (1983) also studied faunal turnover in Europe and North America during Cenozoic Era. They examined the number of total, standing, first appearing, disappearing and running mean on the genera and family.

In this work, the first and last appearances of mammalian taxa from the Neogene Sub-Saharan Africa are considered in detail. The "Half-life" of fauna is analyzed in each order of mammals and each faunal set (mammalian stage in Sub-Saharan Africa). Furthermore, the faunal turnover of Sub-Saharan mammal through late Miocene is discussed.

Table 7 shows range of the first appearance and last appearance of mammalian taxa (mainly species and genera of large mammals) from Neogene Sub-Saharan Africa.

Figure 14 is the numbers of the first, last appearance and total taxa in each faunal set. The number of the first appearance line has two peaks. The first peak (Set IV) indicates the appearance of the new Astaracian taxa. The second peak (Set VII) shows the appearance of the Pliocene taxa. The intermediate zone between two peaks (Set V and VI) also shows the appearance of the new late Miocene taxa. The number of the last appearance line has one broad peak. This peak (Set IV to VI) indicates constant extinction from the Astaracian to Turolian. The first and second peak of first appearance is comparable to the broad peak of the last appearance. The number of total taxa has one peak (Set IV). This peak shows rich faunal assemblage of the intermediate zone of old and new faunas in Miocene.

Figure 15 is the percentage of the first and last appearance of taxa by total taxa of each faunal set. The percentage of the first appearance has three peaks; the first peak (Pre Set I and Set I) indicates the first diversity of the Neogene fauna in the Sub-Saharan Africa, the second peak (Set IV) shows the diversity of middle Miocene fauna after the extinction of early Miocene taxa and the third peak (Set VII) indicates the diversity of late Miocene fauna after the extinction of middle Miocene taxa. The percentage of the last appearance shows one broad peak. The beginning of the peak (Set IV) indicates the extinction of many early Miocene taxa, the middle of the peak (Set V) shows the extinction of many early to middle Miocene taxa. The maximum of the peak indicates the extinction of almost all middle Miocene and some early late Miocene taxa. The second and third peak of first appearance is comparable to the broad peak of the last appearance. There is large gap of faunal turn over between Faunal Set III and IV. It is evident that this gap indicates some paleoenvironmental change.

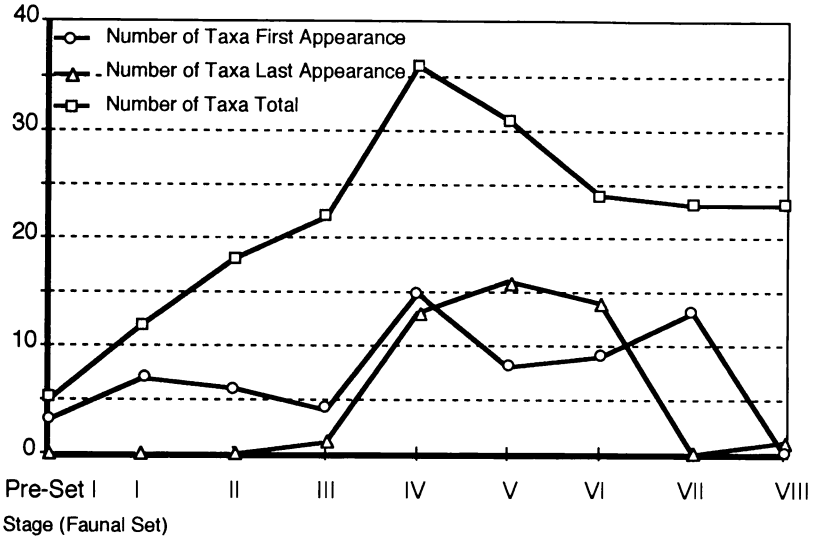


Fig. 14. Number of the total, first appearance and last appearance mammalian taxa of each Faunal Set from the Neogene Sub-Saharan Africa.

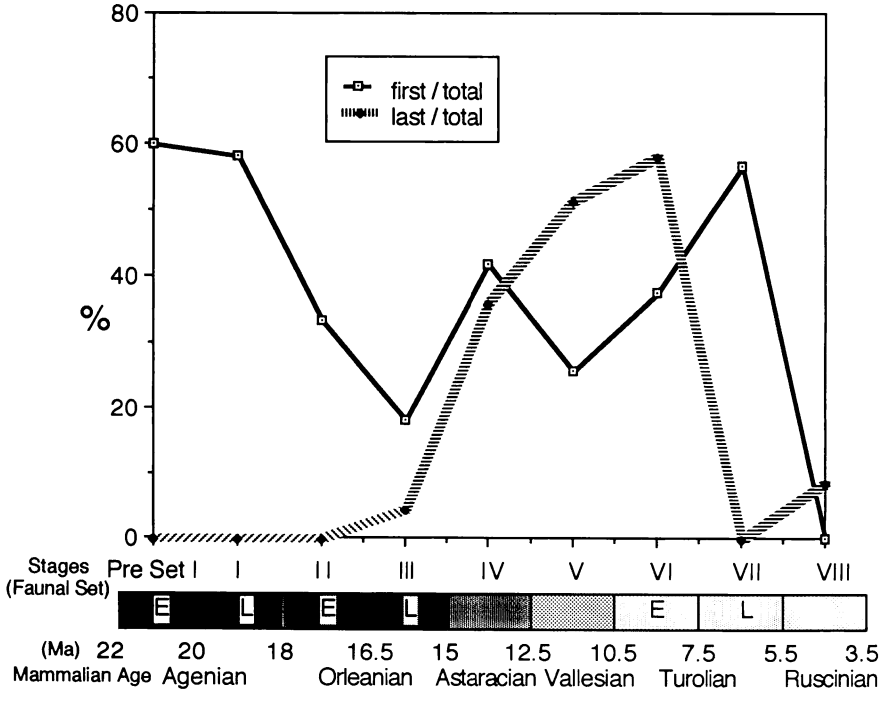


Fig. 15. Percentage of the first appearance and last appearance mammalian taxa by total taxa of each Faunal Set from the Neogene Sub-Saharan Africa.

Table 8. Half-life of the total taxa of the mammalian faunas from the Neogene Sub-Saharan Africa.

Stage	FA0	I	II	III	IV	V	VI	VII	VIII
LA VIII	0	0	1	0	0	3	6	13	0
VII	0	0	0	0	0	0	0	0	
VI	0	1	2	0	5	3	3		
V	1	2	0	3	8	2			
IV	4	4	3	0	2				
III	0	0	0	1					
II	0	0	0						
I	0	0							
Pre-Set I	0								
Number	67								

Cumulate	FA0	I	II	III	IV	V	VI	VII	VIII
LA VIII	0	0	1	1	1	4	10	23	23
VII	0	0	1	1	1	4	10	23	
VI	0	1	4	4	9	15	24		
V	1	4	7	10	23	31			
IV	5	12	18	21	36				
III	5	12	18	22					
II	5	12	18						
I	5	12							
Pre-Set I	5								

Stage	Previous	Next	Average	Half-life	HL Av.	Mean Long.
1stage	67.196	74.269	70.556	1.987	1.987	5.744
2stage	38.418	45.946	41.846	1.591	1.789	5.171
3stage	20.755	26.613	23.322	1.428	1.669	4.824
4stage	10.949	16.129	13.043	1.361	1.592	4.601
5stage	3.960	7.018	5.063	1.162	1.506	4.352
6stage	1.429	2.857	1.905	1.050	1.430	4.133
7stage	0.000	0.000	0.000			
8stage	0.000	0.000	0.000			

Result of "Half-life" analysis to total taxa.

Total time range	17 Ma	Half-life(Av.)	1.430 Stages
Number of faunal set	9 Stages	Mean Long.	4.133 Stages
Average of fauna range	1.889 Ma	Longevity	2.909 Stages
Half-life of fauna	2.701 Ma	Long. (all)	2.552 Stages
Range of fauna	7.806 Ma		

Note; Left upper table shows number of first and last appearance of total taxa. Left lower table shows cumulate number of first and last appearance of total taxa. Right upper table shows the result of calculation of "Half-life" in previous and next stage and average of each stages. HL; half-life, FA; first appearance, LA; last appearance, Long.; longevity, Av.; average.

In the next faunal analysis, the author examines half-life of fauna in Neogene Sub-Saharan Africa. Late Professor Björn Kurtén of University of Helsinki proposed "Half-life" concept (Kurtén, 1959, 1972, 1988). Following Kurtén, the half-life is based on the distribution by first and last appearances of taxa during unit stage, and is calculated by the cumulative distribution showing the total number of taxa, belonging to different temporal strata, present at a given time. The average percentage of previous-stages and next-stage taxa in a given fauna is obtained. The results happen to be identical in this case, but this is not always the case. A weighted mean percentage is obtained. The half-life, expressed with the local age as a unit is calculated. Weighted mean percentages for temporal strata in faunas two stages apart are obtained in analogous way. The half-life is calculated on this basis. In this case, three-stages survival could be used to check the estimates based on one and two-stage survival, and the author repeated the same calculation until stage that reveals no survival. The half-life of fauna is different on the basis of taxa, space and time. The author calculate the half-life and mean longevity of fauna based on taxa and faunal sets.

In the case of half-life of fauna based on taxa, half-life of total taxa is 1.43 (Faunal set) stage (2.70 Ma) (Table 8), Proboscidea is 1.99 stage (3.75 Ma), Perissodactyla is 1.79 stage (3.38 Ma), Carnivora (including Creodonta) is 1.52 stage (2.87 Ma), Artiodactyla is 1.48 stage (2.79 Ma), Primates is 1.30 stage (2.46 Ma), Hyracoidea is 1.52 stage (2.88 Ma), Rodentia is 2.53 stage (4.77 Ma).

Rodentia has the longest half-life of fauna, but this sample consists of only two taxa. These taxa were added in the Namurungule Fauna. Therefore the half-life of Rodentia is not discussed. Hyracoidea also consists of two taxa, therefore the half-life of this taxon is not discussed in this work. The half-life of Primates (2.46 Ma) is the shortest in the taxa of the Sub-Saharan Africa. Proboscidea (3.75 Ma) has the longest half-life in large mammal (Fig. 16). Kurtén (1972) estimated specific half-life during the Cenozoic Era. In Miocene to early Pleistocene, Proboscidea (2.4 Ma) has the longest half-life and Carnivora (1.6 Ma) has the shortest half-life. The value of half-life of Sub-Saharan Africa is longer than Kurtén's result. This result is based on the difference of area and taxonomic hierarchy. Because taxonomic hierarchy is used in not only species but also genera in the case of Sub-Saharan Africa. Furthermore, the faunal half-life of taxa from Sub-Saharan Africa seems to be more stable than that from Eurasia.

In the case of half-life of fauna based on each faunal set (stage), half-life of total taxa of Pre-Set I is 3.93 (Faunal Set) stage (7.4 Ma), Set I is 2.82 stage (5.3 Ma), Set II is 2.43 stage (4.6 Ma), Set III is 2.17 stage (4.1 Ma), Set IV is 1.70 stage (3.2 Ma), Set V is 1.62 stage (3.1 Ma), Set VI is 1.66 stage (3.1 Ma), Set VII is 1.56 stage (2.9 Ma) and Set VIII is 1.56 stage (2.9 Ma). The half-life of total taxa on each faunal set decreases to set III and is constant from set IV to VIII in Neogene of Sub-Saharan Africa (Fig. 17). This result indicates large gap of faunal turn over between Faunal Set III and IV and the increasing of the faunal stability after Faunal Set IV (Astaracian) in Sub-Saharan Africa.

The rise and fall of the total taxa of each Faunal Set from the Neogene Sub-Saharan Africa on the basis of half-life is examined. The following diagram shows the rising and falling curve by a logarithmic scale of each faunal set (Fig. 18). The inclination of rising

curve is changed to steeper between Faunal Set III and IV. It indicates that the rate of faunal turnover is increased after Faunal Set IV (Astaracian).

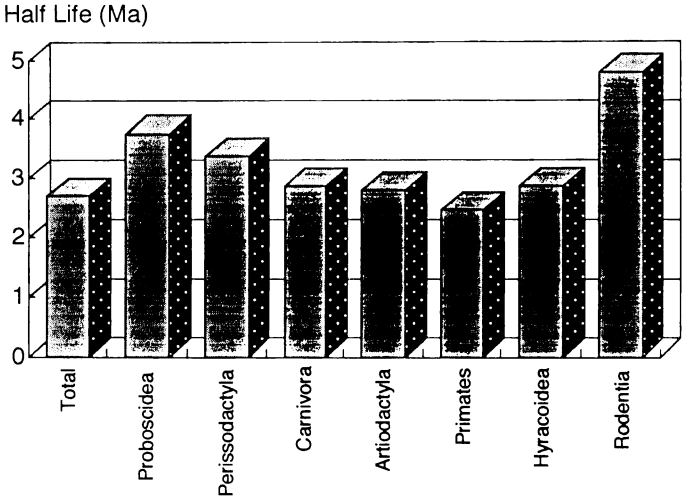


Fig. 16. Half-life of the total and each taxa of the mammalian faunas from the Neogene Sub-Saharan Africa.

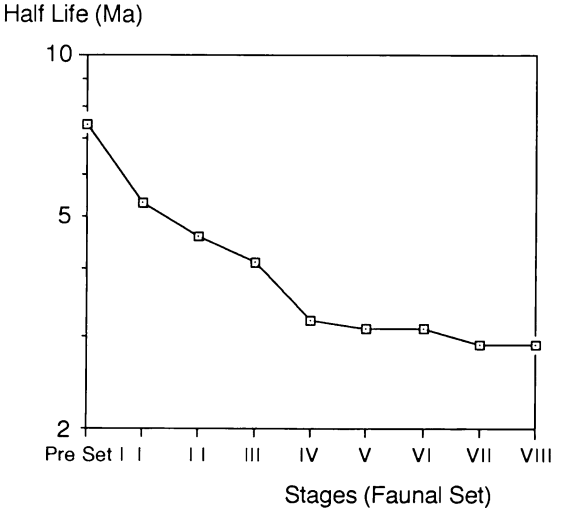


Fig. 17. Half-life of the total taxa of the mammalian faunas from each Faunal Sets of the Neogene Sub-Saharan Africa.

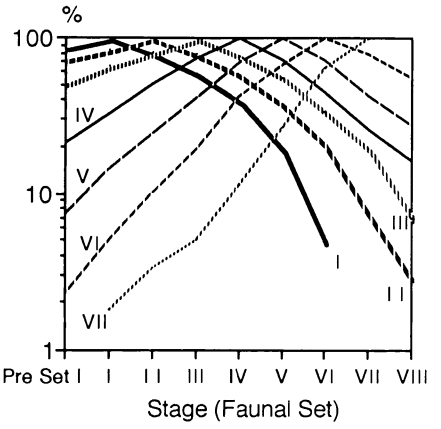


Fig. 18. Diagrammatic representation of the rise and fall of the total taxa of Faunal Set I to VII from the Neogene Sub-Saharan Africa on the basis of half-life.

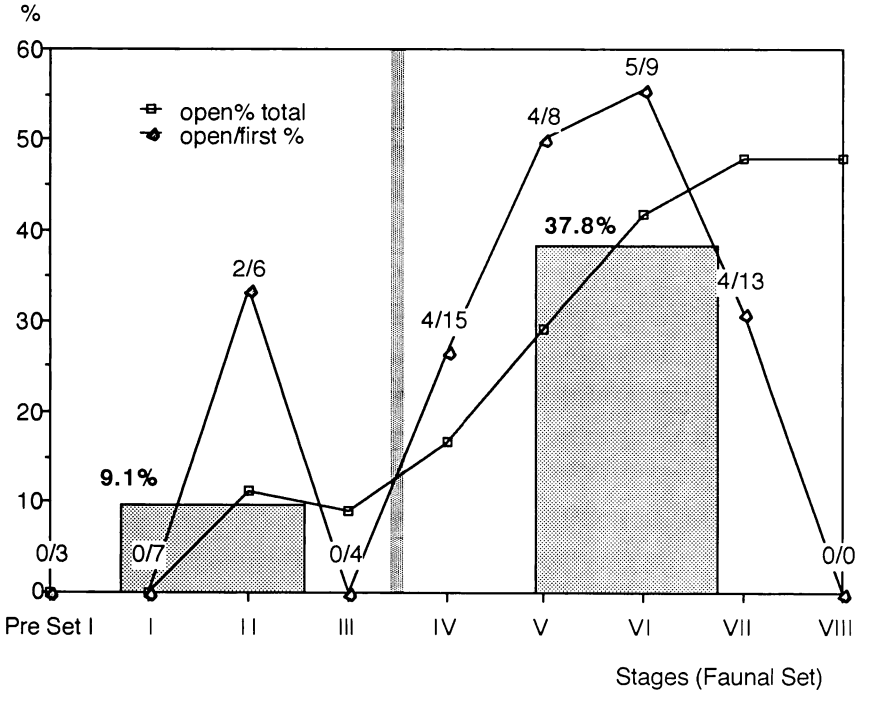


Fig. 19. Increase of the open land taxa.
Solid line: percentage of the open land taxa number in the total taxa number. Gray line: percentage of the first appearance open land taxa in the first appearance taxa. Number on the gray line: number of the first appearance open land taxa in the first appearance taxa. Box symbol: average percentage of the open land taxa number by the total taxa number (left: the average percentage during Pre-Set I to Set III, right: the average percentage during Set IV to Set VIII).

As mentioned above, some geological event occurred at late Orleanian to Astaracian (approximately 15-16 Ma). This geological event might be caused by the increasing of the taxa of the indicators (Equidae, Bovidae and some Suidae) of the open-country and/or open woodland environments in the Sub-Saharan Africa. The percentage of the open land taxa number by the total taxa number increases after Faunal Set IV. The number and percentage of the first appearance of open land taxa by the first appearance taxa increases after Faunal Set IV also. The average percentage of the open land taxa number by the total taxa number during Faunal Set IV to VIII (37.8 %) is clearly larger than the average percentage of the open land taxa number by the total taxa number during Faunal Set Pre-Set I to III (9.1 %) (Fig. 19).

CONCLUSION

I. Late Miocene Mammalian Interchange of Eurasian and Sub-Saharan Africa

Coryndon & Savage (1973), Thomas (1979, 1981) and Bernor (1983, 1984) emphasized close resemblance between the Miocene Sub-Saharan and Siwalik faunas on the basis of some taxonomic research.

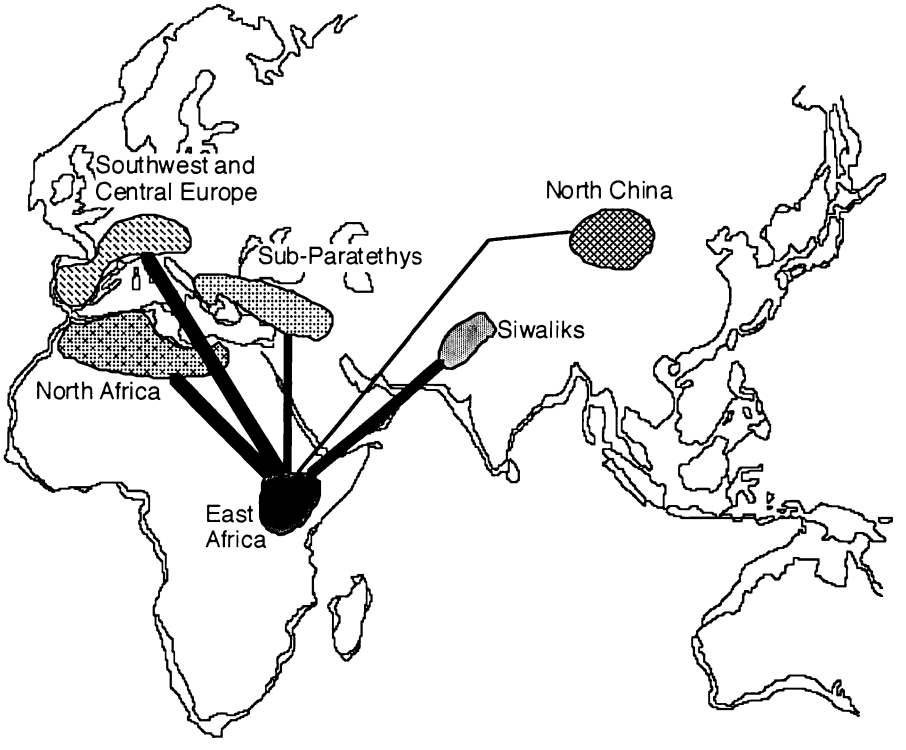


Fig. 20. Faunal resemblance of the Namurungule Fauna and Eurasian faunas.

Phylogenetic research of mammalian taxa of the Namurungule Fauna indicates a similarity to the Turolian faunas from Sub-Paratethys and North Africa. The Miocene mammalian faunas of Sub-Saharan Africa shows resemblance with late Vallesian to Turolian of North Africa, Sub-Paratethys, Southwest and Central Europe faunas based on Simpson's index of faunal resemblance and cluster analysis based on the dissimilarity of mammalian faunas (Fig. 20). The close resemblance between the Miocene Sub-Saharan and Siwalik mammalian faunas should not to be stressed in earlier studies.

II. Late Miocene Faunal Change of Sub-Saharan Africa

Maglio (1978) briefly states the stability of the Miocene mammalian faunas on the basis of the patterns of faunal evolution of Africa.

Assemblage of the mammalian faunas from early Miocene was comparatively stable and had long half-life in Sub-Saharan Africa on the basis of the results of this work.

However, mammalian assemblage changed drastically at the middle Miocene (Astaracian) in Sub-Saharan Africa. A great number of early to middle Miocene mammalian taxa were extinct and the modern mammalian taxa appeared in this period. The half-life of middle and late Miocene mammalian faunas is shortened compared with the early Miocene faunas in the East Africa. This geological event of faunal turnover occurred by the immigration and divergence of open land taxa. It is evident that the rise of open land taxa is related to the environmental change for the plateau phonolite and basalt volcanism in the middle Miocene East Africa (Pickford, 1981; Williams & Chapman, 1986) and the worldwide warm and arid event (savannitisation) of continental temperate zone in the middle to late Miocene (Liu, 1988). In the middle Miocene (16 Ma) Pacific region, it has been proposed that the tropical event is recognized from shallow marine faunas of the Southwestern Japan (Tsuchi, 1986; Ogasawara, 1988). African and Eurasian land connection was also established before the middle Miocene (16 Ma±) (Bernor et al., 1980). The age of the middle Miocene mammalian turnover indicates similar age of the 21st. peak of periodical extinction of marine animals (Sepkoski, 1986; McGhee, 1989). However, Patterson & Smith (1989) denied periodicity in extinction on the basis of omitting noise component of non-monophyletic group. They considered that some peaks of extinction was recognized on the basis of peaks in diversity. This middle Miocene peak of extinction also suggests the diversity of marine animals followed by marine tropical event.

The Astaracian faunal turnover in Sub-Saharan Africa is considered to be caused by immigration and diversity of open country mammalian taxa and that was related to the worldwide middle Miocene warm event and the plateau volcanism in middle Miocene East Africa.

Furthermore, the Pleistocene and modern taxa and their direct ancestors of Sub-Saharan Africa appeared from the late Miocene faunas of East Africa. It has been made clear that the Namurungule Fauna is the forerunner of the modern Sub-Saharan mammalian fauna of savanna environments.

III. Application to the Human Evolution

As mentioned before, the Hominoid Fossil was found from the Namurungule Formation. The savannitisation in the Sub-Saharan Africa began in middle Miocene, which is related to the similar condition happened in Eurasian continent from middle to late Miocene. It should be emphasized that the more advanced development and spreading of open-country environments in the Sub-Saharan Africa compared with Eurasian arid event played an important role in the Hominoids evolution. Because, the bipedalism is the most important character of Hominidae which is distinguished from large ape. The origin of bipedalism seems to be closely related to the environmental change from forest to open land (Foley, 1984).

Human evolution in East Africa is accelerated by the savannitisation of Sub-Saharan Africa which commenced earlier than that of Eurasia and continued throughout the Neogene.

SUMMARY

The Namurungule Fauna indicates a close similarity with the Turolian faunas from Sub-Paratethys and North Africa. The Miocene mammalian faunas of Sub-Saharan Africa shows resemblance with late Vallesian to Turolian of North Africa, Sub-Paratethys, Southwest and Central Europe faunas.

Mammalian assemblage has changed drastically during the middle Miocene (Astaracian). This geological event of faunal turn over is marked by the increase of open land taxa. It indicates the spreading of the warm and arid environments (savannitisation) in the middle to late Miocene East Africa.

Furthermore, the Pleistocene and modern taxa appeared from the late Miocene East African faunas. The Namurungule Fauna is the pioneer of the modern Sub-Saharan mammalian fauna of savanna environments.

The advanced savannitisation in the Sub-Saharan Africa played an important role in the hominization that human ancestors got bipedalism which is caused by their invasion from forest to savanna environments.

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REFERENCES

Adams, C.G., A.W. Gentry & P.J. Whybrow 1983. Dating the terminal tethyan event. *Utrecht Micropal. Bull.*, 30: 273-298.

Aguirre, E. & C. Guérin 1974. Premiere decouverte d'un Iranotheriinae (Mammalia, Perissodactyla, Rhinocerotidae) en Afrique: *Kenyatherium bishopi* nov. gen. nov. sp. de la formation vallesiene (Miocene superieur) de Nakali (Kenya). *Estud. Geol.*, 30: 229-233.

_____ & P. Leakey 1974. Nakali: nueva fauna de *Hipparion* del Rift Valley de Kenya. *Estud. Geol.*, 30: 219-227.

Andersson, J.G. 1923. Essays on the Cenozoic of Northern China. *Mem. Geol. Surv. China, Ser. A*, 3: 1-152.

Andrews, P., G.E. Meyer, D.R. Pilbeam, J.A. Van Couvering & J.A.H. Van Couvering 1981. The Miocene fossil beds of Maboko island, Kenya: geology, age, taphonomy and paleoecology. *J. Human Evolution*, 10 (1): 35-48.

Arambourg, C. 1959. Vertébrés continentaux du Miocène supèrieur de l'Afrique du nord. *Publ. Service Carte Géol. l'Algérie (N. S.) Paléontol. Mém*, 4: 1-159, 18 pls.

_____ 1968. Les vertébrés du Pléistocène de l'Afrique du nord. *Archives Muséum Nat. d'Hist. Nat.* 7 sér, 10: 1-126., 24 pls.

Behrensmeyer, A.K. 1976. Lothagam Hill, Kanapoi, and Ekora: a general summary of stratigraphy and faunas. In (Y. Coppens, F.C. Howell, G.I. Isaac & R.E.F. Leakey, eds.) *Earliest Man and Environments in the Lake Rudolf Basin*, pp. 163-170, Univ. Chicago Press, Chicago.

Benefit, B.R. & M. Pickford 1986. Miocene fossil cercopithecoids from Kenya. *Amer. J. Phys. Anthropol.*, 69: 441-464.

Bernor, R.L. 1983. Geochronology and zoogeographic relationships of Miocene Hominoidea. In (R.L. Ciochon & R.S. Corruccini, eds.) *New Interpretations of Ape and Human Ancestry*, pp. 21-64, Plenum Press, New York.

_____ 1984. A zoogeographic theater and biochronologic play: the time/biofacies phenomena of Eurasian and African Miocene mammal provinces. *Paléobiol. continentale, Montpellier*, 14 (2): 121-142.

_____ 1986. Mammalian biostratigraphy, geochronology, and zoogeographic relationships of the late Miocene Maragheh Fauna, Iran. *J. Vertebr. Paleontol*, 6: 76-95.

_____ & S.T. Hussain 1985. An assessment of the systematic, phylogenetic and biostratigraphic relationships of Siwalik hipparionine horses. *J. Vertebr. Paleontol.*, 5 (1): 32-87.

_____ & P.P. Pavlakis 1987. Zoogeographic relationships of the Sahabi large mammal fauna (early Pliocene, Libya). In (N.T. Boaz, A. El-Arnauti, A.W. Gaziry, J. de Heinzelin & D.D. Boaz, eds.)*Neogene Paleontology and Geology of Sahabi*, pp. 349-383. Alan R. Liss, Inc.,

New York.

_____, M.O. Woodburne & J.A. Van Couvering 1980. A contribution to the chronology of some old world Miocene faunas based on hipparionine horses. *Geobios*, 13 (5): 705-739.

Bishop, W.W. 1962. The mammalian fauna and geomorphological relations of the Napak volcanics, Karamoja. *Records of the Geological Survey of Uganda*, 1957-58: 1-18.

_____ 1967. The later Tertiary in east Africa- volcanics, sediments, and faunal inventory. In (W.W. Bishop & J.D. Clark, eds.) *Background to Evolution in Africa*, pp. 31-56, Univ. Chicago Press, Chicago.

_____ & M. Pickford 1975. Geology, fauna and palaeoenvironments of the Ngorora Formation, Kenya Rift Valley. *Nature* 254: 204-208.

Boaz, N.T., A. El-Arnauti, A.W. Gaziry, J.de Heinzelin & D.D. Boaz (eds.) 1987. *Neogene Paleontology and Geology of Sahabi*. Alan R. Liss, Inc., New York.

Bohlin, B. 1937. Eine Tertiare Saugetier-Fauna aus Tsaidam. *Palaeontol. Sinica Ser. C*, 14 (1): 14-19.

Boné, E.L. & R. Singer 1965. *Hipparion* from Langebaanweg, Cape Province and a revision of the genus in Africa. *Ann. S. Afr. Mus.* ,48 (16): 273-397, pl. 7-19.

Bonnefille R., A. Vincens & G. Buchet 1987. Palynology, stratigraphy and paleoenvironment of a Pliocene Hominid site (2.9-3.3 m.y.) at Hadar, Ethiopia. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 60: 249-281.

Bouvrain, G. & L. de Bonis 1986. *Ouzocerus gracilis* n. g., n. sp., Bovidae (Artiodactyla, Mammalia) du Vallésien (Miocène supérieur) de Macédoine (Grèce). *Geobios*, 19 (5): 661-667.

Butler, P.M. 1978. Chalicotheriidae. In (V.J. Maglio & H.B.S. Cooke, eds.) *Evolution of African Mammals*, pp. 368-370, Harvard Univ. Press, Cambridge.

Chapman, G.R. & M. Brook 1978. Chronostratigraphy of the Baringo basin, Kenya. In (W.W. Bishop, ed.) *Geological Background to Fossil Man*, pp. 207-224, Scottish Academic Press, Edinburgh.

Churcher, C.S. 1978. Giraffidae. In (V.J. Maglio & H.B.S. Cooke, eds.) *Evolution of African Mammals*, pp. 509-535, Harvard Univ. Press, Cambridge.

_____ 1979. The large palaeotragine giraffid, *Palaeotragus germaini*, from late Miocene deposits of Lothagam Hill, Kenya. *Breviora*, 453: 1-8.

Clemens, W.A., J.A. Lillegraven, E.H. Lindsay & G.G. Simpson 1979. Where, when, and what; –A survey of known Mesozoic mammal distribution–. In (J.A. Lillegraven, Z. Kielan-Jaworowska & W.A. Clemens, eds.) *Mesozoic Mammals, The First Two-Thirds of Mammalian History*, pp. 7-58, Univ. Calif. Press, Berkeley.

Colbert, E.H. 1935. Siwalik mammals in the American Museum of Natural History. *Trans. Amer. Phil. Soc. N.S.*, 26: 1-401.

Cooke, H.B.S. & R.F. Ewer 1972. Fossil Suidae from Kanapoi and Lothagam, northwestern Kenya. *Bull. Mus. Comp. Zool.*, 143 (3): 1-295.

Conroy, G.C., M. Pickford, B. Senut, J. Van Couvering & P. Mein 1992. *Otavipithecus namibiensis*, first Miocene hominoid from southern Africa. *Nature*, 356: 144-148.

Coryndon, S.C. & R.J.G. Savage 1973. The origin and affinities of African mammal faunas. In (N.F. Hughes, ed.) *Organisms and Continents through Time. Special Papers in Palaeontology*, 12: pp. 121-135, Syst. Assoc. Publ., London.

Crusafont-Pairo, M. & J.F. de Villalta-Comella 1947. Sobre un interesante Rinoceronte (*Hispanotherium* nov. gen.) del Mioceno del Valle del Manzanares. *Las Ciencias* 12: 869-883.

Darwin, C. 1871. The descent of man and selection in relation to sex. *Origin of Species and The Descent of Man*: 387-924, 941-1000, Random House, New York.

Dehm, R. & T. zu Oettingen-Spielberg 1958. Paläontologische und geologische Unter-suchungen im Tertiär von Pakistan, 2. Die mitteleocänen Säugetiere von Ganda Kas bei Basel in Northwest-Pakistan. *Abh. Bayer. Akad. Wissen. Math.-Natur.Kl.N.F.*, 91: 1-54, 3 pls.

_____, _____ & H. Vidal 1958 Paläontologische und geologische Untersuchungen im Tertiär von Pakistan, 1. Die Münchner Forschungsreise nach Pakistan 1955-1956. *Abh. Bayer. Akad. Wissen. Math.-Natur. Kl. N.F.*, 90: 1-13.

_____, _____ & _____ 1963. Paläontologische und geologische Untersuchungen im Tertiär von Pakistan, 3. Dinotherium in der ChinjStufe der Unteren Siwalik-Schichten. *Abh. Bayer. Akad. Wissen. Math.-Natur. Kl. N.F.*, 114: 1-34, 2 pls.

Drake, R.E. & G.H. Curtis 1987. K-Ar geochronology of the Laetoli fossil localities. In (M.D. Leakey & J.M. Harris, eds.) *Laetoli, a Pliocene Site in Northern Tanzania.*, pp. 48-52, Oxford Scientific Publications, Clarendon Press, Oxford.

_____, J.A. Van Couvering, M. Pickford, G.H. Curtis & J.A. Harris 1988. New chronology for the early Miocene mammalian faunas of Kisingiri, western Kenya. *J. Geol. Soc. London*, 145: 479-491.

Eisenmann, V. 1977. Les *Hipparion africanus*: valeur et signification de quelques caracteres des jungales inferieures. *Bull. Mus. Natl. Hist. Nat. Ser. 3, Sci. Terre*, 60 (438): 69-86; 1 pl.

_____ 1979. Le genre Hipparion (Mammalia, Perissodactyla) et son interet biostratigraphique en Afrique. *Bull. Soc. Géol. Fr. Ser. 7*, 21 (3): 277-281.

_____ 1982. La phylogenie des Hipparion (Mammalia, Perissodactyla) d'Afrique d'apres les caracteres craniens. *Proc.K. Ned. Akad. Wet. Ser. B*, 85 (2): 219-227.

Falconer, H. & P.T. Cautley, 1846-1849. *Fauna Antiqua Sivalensis*, part 1-9, London.

Flynn, L.J., L.L. Jacobs & S. Sen 1983. La diversité de *Paraulacodus* (Thryonomyidae, Rodentia) et des groupes apparentés pendant le Miocène. *Ann. Paléontol. (Vert.-Invert.)*, 69: 355-366.

Foley, R. 1984. Early man and the red queen: tropical African community evolution and hominid adaptation. In (R. Foley, ed.) *Hominid Evolution and Community Ecology*, pp. 85-110, Academic Press, London.

Forstén, A. 1968. Revision of the Palearctic *Hipparion*. *Acta Zool. Fenn.*, 119: 1-134.

_____ 1972. *Hipparion primigenium* from southern Tunisia. *Notes Serv. Géol. no.35 Trav. Géol. Tunisienne*, no. 5 (Formation Beglia) fasc. 1: 7-28.

_____ 1978. *Hipparion primigenium* (V. Meyer, 1829), an early three-toed horse. *Ann. Zool. Fenn.*, 15: 298-313.

_____ 1979. Revision of two *Hipparion* species from the upper Miocene of the USSR. *Paleontol. J.*, 1979 (4): 112-118.

_____ 1980a. Hipparions of the *Hipparion mediterraneum* group from south-western USSR. *Ann. Zool. Fenn.*, 17: 27-38.

_____ 1980b. How many Hipparion species at Samos? *Neues Jahrb. Geol. Palaeontol. Monatsh.*, 1980 (7): 391-396.

_____ 1981. Correlation of *Hipparion* faunal components in the east Mediterranean and Paratethys areas. *Paleontol. Z.*, 55 (2): 141-155.

_____ 1983. The Preorbital fossa as a taxonomic character in some old world *Hipparion*. *J. Paleontol.*, 57 (4): 686-704.

_____ 1984. Superspecific grouping of old world hipparions (Mammalia, Equidae). *Paleontol. Z.*, 58 (1/2): 165-171.

Gabuniya, L.K. 1959. *K Istorii Gipparionov (History of Hipparion)* (in Russian). Izdatelstvo Akademii Nauk SSSR, Moskva.

Gentry, A.W. 1966. Fossil Antilopini of East Africa. *(Fossil Mammals of Africa 20) Bull. Br.*

Mus. Nat. Hist. (Geol.), 12 (2): 43-106, 9 pls.

_____ 1967. *Pelorovis oldowayensis* Reck, an extinct bovid from east Africa. *(Fossil Mammals of Africa 22) Bull. Br. Mus. Nat. Hist. (Geol.),* 14 (7): 243-299, 6 pls.

_____ 1970. Revised classification for *Makapnia broomi* Wells and Cooke (Bovidae, Mammalia). *Palaeontol. Afr.,* 13: 63-67.

_____ 1971. The earliest goats and other antelopes from the Samos *Hipparion* fauna. *Bull. Br. Mus. Nat. Hist. (Geol.)* 20 (6): 231-296, pl. 1-6.

_____ 1978a. The fossil Bovidae of the Baringo area, Kenya. In (W.W. Bishop, ed.) *Geological Background to Fossil Man,* pp. 293-308, Scottish Academic Press, Edinburgh.

_____ 1978b. Bovidae. In (V.J. Maglio & H.B.S. Cooke, eds.) *Evolution of African Mammals,* pp. 540-572, Harvard Univ. Press, Cambridge.

_____ 1980. Fossil Bovidae (Mammalia) from Langebaanweg, South Africa. *Ann. S. Afr. Mus.,* 79 (8): 213-337.

_____ & A. Gentry 1978. Fossil Bovidae (Mammalia) of Olduvai Gorge, Tanzania. Part 1, 2. *Bull. Br. Mus. Nat. Hist. (Geol.),* 29(4): 289-446, 30 (1): 1-83.

Groves, C.P. 1989. *A Theory of Human and Primate Evolution.* Clarendon Press, Oxford.

Hamilton, W.R. 1973a. The lower Miocene ruminants of Gebel Zelten, Libya. *Bull. Br. Mus. Nat. Hist. (Geol.),* 21 (3): 73-150, 14 pls.

_____ 1973b. North African lower Miocene rhinoceroses. *Bull. Br. Mus. Nat. Hist. (Geol.),* 24 (6): 351-395, 8 pls.

_____ 1978. Fossil giraffes from the Miocene of Africa and a revision of the phylogeny of the Giraffoidea. *Phil. Trans. R. Soc. London, Ser. B,* 283 (996): 165-229.

Harris, J.M. 1973. *Prodeinotherium* from Gebel Zelten, Libya. *Bull. Br. Mus. Nat. Hist. (Geol.),* 23 (5): 283-348, 5 pls.

_____ 1975. Evolution of feeding mechanisms in the family Deinotheriidae (Mammalia: Proboscidea). *Zool. J. Linn. Soc.,* 56 (4): 331-362.

_____ 1976. Cranial and dental remains of *Deinotherium bozasi* (Mammalia: Proboscidea) from East Rudolf, Kenya. *J. Zool. London,* 178: 57-75.

_____ 1977. Deinotheres from southern Africa. *S. Afr. J. Sci.,* 73 (9): 281-282.

_____ 1978. Deinotherioidea and Barytherioidea. In (V.J. Maglio & H.B.S. Cooke, eds.) *Evolution of African Mammals,* pp. 315-335, Harvard Univ. Press, Cambridge.

_____ & R. Watkins 1974. New early Miocene vertebrate locality near Lake Rudolf, Kenya. *Nature,* 252: 576-577.

_____ & T.D. White 1979. Evolution of the Plio-Pleistocene African Suidae. *Trans. Amer. Philos. Soc.,* 69 (2): 1-128.

Heissig, K. 1972. Paläontologische und geologische Untersuchungen im Tertiär von Pakistan. 5. Rhinocerotidae (Mamm.) aus den unteren und mittleren Siwalik-Schichten. *Abh. Bayer. Akad. Wiss. Kl. Math. -Naturwiss. N. F.,* 152: 1-112, 25 pls.

_____ 1974. Neue Elasmotherini (Rhinocerotidae, Mammalia) aus dem Obermiozän Anatoliens. *Mitt. Bayer. Staatssamml. Paläont. hist. Geol.,* 14: 21-35.

Hendey, Q.B. 1974. The late Cenozoic Carnivora of the south-western Cape Province. *Ann. S. Afr. Mus.,* 63: 1-369.

_____ 1978. Preliminary report on the Miocene vertebrates from Arrisdrift, South West Africa. *Ann. S. Afr. Mus.,* 76 (1): 1-41.

Hill, A., R. Drake, L. Tauxe, M. Monaghan, J.C. Barry, A.K. Behrensmeyer, G Curtis, B. Fine-Jacobs, L. Jacobs, N. Johnson & D. Pilbeam 1985. Neogene palaeontology and geochronology of the Baringo basin, Kenya. *J. Human Evolution* ,14: 759-773.

Hooijer, D.A. 1963. Miocene Mammalia of Congo. *Ann. Mus. R. Afr. Cent. Ser. 8, Sci. Geol.*, 46: 1-77, 10 pls.

_____ 1966. Miocene rhinoceroses of East Africa *(Fossil Mammals of Africa, 21). Bull. Br. Mus. Nat. Hist. (Geol.),* 13 (2): 117-190, 15 pls.

_____ 1968. A rhinoceros from the late Miocene of Fort Ternan, Kenya. *Zool. Meded.* 43 (6): 77-92.

_____ 1970. Miocene Mammalia of Congo, a correction. *Ann. Mus. R. Afr. Cent. Ser. 8 Sci. Geol.*, 67: 163-167.

_____ 1971. A new Rhinoceros from the late Miocene of Loperot, Turkana District, Kenya. *Bull. Mus. Comp. Zool.*, 142(3): 339-392.

_____ 1972. A late Pliocene rhinoceros from Langebaanweg, Cape Province. *Ann. S. Afr. Mus.*, 59 (9): 151-191, 14 pls.

_____ 1973. Additional Miocene to Pleistocene rhinoceroses of Africa. *Zool. Meded.*, 46(11): 149-178, 2 pls.

_____ 1975. Miocene to Pleistocene Hipparions of Kenya, Tanzania and Ethiopia. *Zool. Verhand.*, 142: 1-80, 19 pls.

_____ 1976. The late Pliocene Equidae of Langebaanweg, Cape Province, South Africa. *Zool. Verhand.*, 148: 1-39, 8 pls.

_____ 1978. Rhinocerotidae. In (V.J. Maglio & H.B.S. Cooke, eds.) *Evolution of African Mammals*, pp. 371-378, Harvard Univ. Press, Cambridge.

_____ & V.J. Maglio 1973. The earliest Hipparion south of the Sahara in the late Miocene of Kenya. *Proc. K. Ned. Akad. Wet. Ser. B.*, 76 (4): 311-315.

_____ & _____ 1974. Hipparions from the late Miocene and Pliocene of northwestern Kenya. *Zool. Verhand.*, 134: 1-34, 8 pls.

Howell, F.C. 1980. Zonation of late Miocene and early Pliocene Circum-Mediterranean faunas. *Geobios*, 13: 653-657.

Hussain, S.T. 1971. Revision of Hipparion (Equidae, Mammalia) from the Siwalik Hills of Pakistan and India. *Abh. Bayer. Akad. Wiss. Kl. Math. -Naturwiss. N. F.*, 147: 1-68, fig. 4-17, pl. 1-5, tab. 5 a-19.

Ishida, H. 1984. Outline of 1982 survey in Samburu Hills, northern Kenya. *African Study Monographs, Suppl. Issue*, 2: 1-13.

_____, M. Pickford, H. Nakaya & Y. Nakano 1984. Fossil anthropoids from Nachola and Samburu Hills, Samburu District, northern Kenya. *African Study Monographs, Suppl. Issue*, 2: 73-85.

_____ & K. Yasui (eds.) 1992. Palaeontological and geological surveys in the Sinda-Mohari Region of the western Rift, Zaire. *African Study Monographs, Suppl. Issue*, 17, Center for African Area Studies, Kyoto Univ., Kyoto.

Itaya, T. & Y. Sawada (in press). K-Ar ages of volcanic rocks in the Samburu Hills area, Northern Kenya. *African Study Monographs, Suppl. Issue*, 5.

Jacobs, L.L. 1978. Fossil rodents (Rhizomyidae & Muridae) from Neogene Siwalik deposits, Pakistan. *Bull. Mus. Northern Arizona*, 52: 1-103.

_____, J.D. Congleton, M. Brunet, J. Dejax, L.J. Flynn J.V. Hell & G. Mouchelin 1988. Mammal teeth from the Cretaceous of Africa. *Nature*, 336: 158-160.

_____, J. Michaux & M. Sabatier 1980. Premières données sur les rongeurs de la formation de Ch'orora (Ethiopie) d'âge Miocène supérieur, I. Thryonomyidés. *Palaeo-vertebrata, Mém. Jubil. Lavocat*, pp. 365-374, 1 pl.

Kalb, J.E., E.B. Oswald, S. Tebedge, A. Mebrate, E. Tola & D. Peak 1982a. Geology and

stratigraphy of Neogene deposits, Middle Awash Valley, Ethiopia. *Nature*, 298: 17-25.

_____, C.J. Jolly, A. Mebrate, S. Tebedge, C. Smart, E.B. Oswald, D. Cramer, P. Whitehead, C.B. Wood, G.C. Conroy, T. Adefris, L. Sperling & B. Kana 1982b. Fossil mammals and artifacts from the Middle Awash Valley, Ethiopia. *Nature*, 298: 25-29.

_____, _____, S. Tebedge A. Mebrate, C. Smart, E.B. Oswald, D. Cramer, P. Whitehead, C.B. Wood, T. Adefris & V. Rawn-Schatzinger 1982c. Vertebrate faunas from the Awash Group, Middle Awash Valley, Afar, Ethiopia. *J. Vertebr. Paleontol.*, 2 (2): 237-258.

Kamei, T., J. Ikeda, H. Ishida, S. Ishida, I. Onishi, H. Partoazar, S. Sasajima & S. Nishimura 1977. A general report of geological and paleontological survey in Maragheh area, North-west Iran, 1973. *Mem. Fac. Sci. Kyoto Univ. Ser. Geol. & Mineral.*, 43 (1/2): 131-164, pl. 7-9.

Kawamura, Y. & H. Nakaya 1982. Report of field survey in Kirimun Kenya, 1980; –3. Palaeontology–. In (H. Ishida & S. Ishida, eds.) *Study of the Tertiary Hominoids and Their Palaeoenvironments in East Africa.* 1, pp. 65-138, pl.3-16, Osaka University, Osaka.

_____ & _____ 1984. Thryonomyid rodent from the late Miocene Namurungule Formation, Samburu Hills, northern Kenya. *African Study Monographs, Suppl. Issue*, 2: 133-139.

_____ & _____ (in press). Additional materials of the late Miocene rodents from the Namurungule Formation of Samburu Hills, northern Kenya. *African Study Monographs, Suppl. Issue*, 5.

Klipsten, A. & J. Kaup 1836. *Beschreibung und Abbildungen von dem in Rheinhessen aufgefundenen Schädel des* Dinotherii gigantei. Darmstadt.

Koenigswald, R. 1929. Bemerkungen zur Säugetierfauna des rheinhessischen Dinotheriensandes. *Senckenbergiana* 11: 1-267.

Koken, E. 1885. Ueber Fossile Säugethiere aus China. *Palaeontol. Abhand.*, 3(2): 1-85, 7 pls.

Kurtén, B. 1959. On the longevity of mammalian species in the Tertiary. *Comment. Biol. Soc. Sci. Fennica*, 21 (4): 1-14.

_____ 1972. The "Half-Life" concept in evolution illustrated from various mammalian groups. In (W.W. Bishop & J.A. Miller, eds.) *Calibration of Hominoid Evolution*, pp. 187-194, Scottish Acad. Press, Edinburgh.

_____ 1988. *On Evolution and Fossil Mammals.* Columbia Univ. Press, New York.

Lavocat R. 1961. Le gisement de vertébrés fossiles de Beni Mellal. *Notes Mém. Serv. Géol. Maroc*, 155: 1-144.

_____ 1973. Les rongeurs du Miocène d'Afrique orientale, I. Miocène inférieurs. *Mém. Trav. E.P.H.E.*, 1: 1-284, pl. 1-44.

Leakey, M. D. & J. M. Harris (eds.) 1987. *Laetoli, a Pliocene Site in Northern Tanzania.* Oxford Scientific Publications, Clarendon Press, Oxford.

Liu, G.-W. 1988. Neogene climatic features and events of northern China. In (R. Tsuchi, M. Chiji & Y. Takayanagi, eds.) *Neogene Biotic Evolution and Related Events*, pp. 21-30, Osaka Mus. Nat. Hist. Special Publ., Osaka.

MacFadden, B.J. & A. Bakr 1979. The horse *Cormohipparion theobaldi* from the Neogene of Pakistan, with comments on Siwalik hipparions. *Palaeontology*, 22 (2): 439-447.

_____ & M.F. Skinner 1981. Earliest Holarctic *Hipparion, Cormohipparion goorisi* n. sp. (Mammalia, Equidae) from the Barstovian (medial Miocene) Texas Gulf Coastal Plain. *J. Paleontol.*, 55 (3): 619-627.

Maglio, V.J. 1978. Patterns of Faunal Evolution. In (V.J. Maglio & H.B.S. Cooke, eds.) *Evolution of African Mammals*, pp. 603-619, Harvard Univ. Press, Cambridge.

_____ & H.B.S. Cooke (eds.) 1978. *Evolution of African Mammals*, Harvard Univ. Press, Cambridge.

Makinouchi, T., T. Koyaguchi, T. Matsuda, H. Mitsushio & S. Ishida 1984. Geology of the Nachola area and the Samburu Hills, west of Baragoi, northern Kenya. *African Study Monographs, Suppl. Issue,* 2: 15-44.

Martin, L. 1986. Relationships among extant and extinct great apes and humans. In (B. Wood, L. Martin & P. Andrews, eds.) *Major Topics in Primate and Human Evolution,* pp. 161-187, Cambridge Univ. Press, Cambridge.

Matsuda, T., M. Torii, T. Koyaguchi, T. Makinouchi, H. Mitsushio & S. Ishida 1986. Geochronology of Miocene hominoids, east of the Kenya Rift Valley. In (J.G. Else & P.C. Lee, eds.) *Primate Evolution,* 1: pp.35-45, Cambridge Univ. Press, Cambridge.

McGhee, G.R. 1989. Catastrophes in the history of life. In (K.C. Allen & D.E.G. Briggs, eds.) *Evolution and the Fossil Record,* pp. 26-50, Belhaven Press, London.

Mecquenem, R. de 1908-1911. Contribution a l'étude du gisement des Vertébrés de Maragha et de ses environs. *Ann. d'Hist. Natur. Paléontol.,* 1: 1-98, 17 pls.

_____ 1924-1925. Contribution à l'étude des fossiles de Maragha. *Ann. Paléontol.,* 13: 133-160, pl. 19-22, 14: 1-36, pl. 1-5.

Moonen, J.J.M., P.Y. Sondaar & S.T. Hussain 1978. A comparison of large fossil mammals in the stratotypes of the Chinji, Nagri and Dhok Pathan Formations (Punjab, Pakistan). *Proc. K. Ned. Akad. Wet. Ser. B,* 81 (4): 425-436.

Nakajima, T. & M. Torii, (in press). Paleomagnetism of Miocene rocks in the western area of Baragoi, northern Kenya. *African Study Monographs, Suppl. Issue,* 5.

Nakaya, H. 1987. The Neogene mammalian fauna of the Sub-Saharan Africa (in Japanese with English abstract). *Africa Kenkyu (J. African Studies),* 30: 107-115.

_____ 1989. Late Miocene mammalian interchange of Sub-Saharan Africa –palaeoenvironments of large hominoids evolution–. In (G. Giacobini, ed.) *Hominidae; –Proceed. 2nd. International Cong. Human Paleontol.–,* pp. 67-70, Jaca Book, Milano.

_____ 1993. Mammalian fauna of late Miocene Samburu Hills, Kenya, East Africa and environments of pre-hominids. *L'Anthropologie,* 97 (1): 9-16.

_____, M. Pickford, Y. Nakano & H. Ishida 1984. The late Miocene large mammalian fauna from the Namurungule Formation, Samburu Hills, northern Kenya. *African Study Monographs, Suppl. Issue,* 2: 87-131.

_____, _____, K. Yasui & Y. Nakano (in press). Additional large mammalian fauna from the Namurungule Formation, Samburu Hills, northern Kenya. *African Study Monographs, Suppl. Issue,* 5.

_____ & M. Watabe 1990. Hipparion from the upper Miocene Namurungule Formation, Samburu Hills, Kenya: phylogenetic significance of newly discovered skull. *Geobios,* 23 (2): 195-219.

Ogasawara, K. 1988. Neogene bio-events in terms of warm- and cold-water Molluscs in Northeast Honshu, Japan (in Japanese with English abstract). In (R. Tsuchi, M. Chiji & Y. Takayanagi, eds.) *Neogene Biotic Evolution and related Events,* pp. 49-70, Osaka Mus. Nat. Hist. Special Publ., Osaka.

Opdyke, N.D., E. Lindsay & G.D. Johnson 1979. Magnetic polarity stratigraphy and vertebrate paleontology of the upper Siwalik Subgroup of northern Pakistan. *Palaeogeogr. Palaeoclimatol. Palaeoecol.,* 27: 1-34.

Osborn, H.F. 1936. The Deinotheres (Deinotherioidea) of western Eurasia and of Africa. In *Proboscidea,* 1, pp 81-117, Amer. Mus. Nat. Hist., New York.

Patterson, C & A.B. Smith 1989. Periodicity in extinction: the role of systematics. *Ecology,* 70 (4): 802-811.

Pickford, M. 1978a. Geology, palaeoenvironments and vertebrate faunas of the mid-Miocene

Ngorora Formation, Kenya. In (W.W. Bishop, ed.) *Geological Background to Fossil Man*, pp. 237-262, Scottish Academic Press, Edinburgh.

_____ 1978b. Stratigraphy and mammalian palaeontology of the late-Miocene Lukeino Formation, Kenya. In (W.W. Bishop, ed.) *Geological Background to Fossil Man*, pp. 263-278, Scottish Academic Press, Edinburgh.

_____. 1981. Preliminary Miocene mammalian biostratigraphy for western Kenya. *J. Human Evolution*, 10 (1): 73-97.

_____ 1982. Report of Invertebrate from Kirimun. In (H. Ishida & S. Ishida, eds.)*Study of the Tertiary Hominoids and Their Palaeoenvironments in East Africa.* 1, pp. 140-145, pl. 17-18, Osaka University, Osaka.

_____ 1983. On the origins of Hippopotamidae together with descriptions of two new species, a new genus and a new subfamily from the Miocene of Kenya. *Geobios*, 16 (2): 193-217.

_____ 1986a. Sedimentation and fossil preservation in the Nyanza Rift system, Kenya. In (L.E. Frostick, R.W. Renaut, I. Reid & J.-J. Tiercelin, eds.)*Sedimentation in the African Rifts, Geol. Soc. Special Publ.*, 25, pp. 345-362, Blackwell, Oxford.

_____ 1986b. Cainozoic paleontological sites of western Kenya. *Müncher Geowiss. Abhandl. Reihe A, Geol. und Paläontol.*, 8: 1-151.

_____ 1988. Revision of the Miocene Suidae of the Indian subcontinent. *Müncher Geowiss. Abhandl. Reihe A, Geol. und Paläontol.*, 12: 1-91.

_____, H. Ishida, Y. Nakano,& H. Nakaya 1984. Fossiliferous localities of the Nachola-Samburu Hills area, northern Kenya. *African Study Monographs, Suppl. Issue*, 2: 45-56.

_____ & N. Kuga (in press). The fauna from the Nachola Formation, Samburu Hills, northern Kenya. *African Study Monographs, Suppl. Issue*, 5.

Pilbeam, D., J. Barry, G.E. Meyer, S.M.I. Shah, M. Pickford, W.W. Bishop, H. Thomas & L.L. Jacobs 1977. Geology and palaeontology of Neogene strata of Pakistan. *Nature*, 270: 684-689.

Pilgrim, G.E. 1913. Correlation of the Siwaliks with mammal horizons of Europe. *Rec. Geol. Surv. India*, 43(3): 264-326, pls. 26-28.

Qiu, Z.-X., W.-L. Huang & Z.-H. Guo 1987. The Chinese hipparionine fossils (in Chinese with English abstract). *Palaeontol. Sinica* 175, *New Ser. C*, 25: 1-250, 47 pls.

Ringström, T.J. 1922. *Sinotherium lagrelii* Ringström, a new fossil rhinocerotid from Shansi, China. *Bull. Geol. Surv. China*, 5: 91-93.

_____ 1924. Nashorner der Hipparion-Fauna Nord-Chinas. *Palaeontol. Sinica Ser. C*, 1 (4): 1-156, 12 pls.

_____ 1927. Über quartäre und jungtertiäre Rhinocerotiden aus China und der Mongolei. *Palaeontol. Sinica Ser. C*, 4 (3): 1-21, pl. 1-2.

Robinson, P. 1972. *Pachytragus solignaci*, a new species of caprine bovid from the late Miocene Beglia Formation of Tunisia. *Notes Serv. Géol. Tunisia*, 37: 73-94.

_____ & C.C. Black 1969. Note préliminaire sur les vertébrés fossiles du Vindobonien (formation Beglia), bu Bled Dourah, Gouvernorat de Gafsa, Tunisia. *Notes Serv. Géol. Tunisia*, 31: 67-70.

Savage, D.E. 1978. Carnivora. In (V.J. Maglio & H.B.S. Cooke, eds.) *Evolution of African Mammals*, pp. 249-267, Harvard Univ. Press, Cambridge.

_____ & D.E. Russell, 1983. *Mammalian Paleofaunas of the World.* Addison-Wesley Publishing Company Inc., Reading.

Sawada, Y., M. Tateishi & S. Ishida, (in press). Geology of the Neogene system in and around Samburu Hills, northern Kenya. *African Study Monographs, Suppl. Issue*, 5.

Schlosser, M. 1924. Tertiary vertebrates from Mongolia. *Palaeontol. Sinica Ser. C*, 1 (1): 1-119, 6

pls.

Schmidt-Kittler, N. 1976. Raubtiere aus dem Jungtertiar Kleinasiens (Carnivores from the Neogene of Asia Minor). *Palaeontographica. Abt. A,* 155: 1-131, pl. 1-5.

_____ 1987. The Carnivora (Fissipedia) from the lower Miocene of East Africa. *Palaeontographica. Abt. A,* 197: 85-126, 4 pls.

Sepkoski, J.J. 1986. Phanerozoic overview of mass extinction. In (D. Raup & D. Jablonski, eds.) *Patterns and Processes in the History of Life,* pp. 277-295, Springer-Verlag, Berlin.

Shuey, R.T., H.B. Frank, G.G. Eck & F.C. Howell 1978. A statistical approach to temporal biostratigraphy. In (W.W. Bishop, ed.) *Geological Background to Fossil Man,* pp. 103-124, Scottish Academic Press, Edinburgh.

Sigogneau-Russell, D., M. Monbaron & D.E. Russell 1988. Découverte de Mammifères dans le Mésozoïque moyen d'Afrique. *C. R. Acad. Sci. Paris sér. II,* 307: 1045-1050.

Simons, E.L. 1961. The phyletic position of *Ramapithecus. Postilla,* 57: 1-9.

_____, P. Andrews & D.R. Pilbeam 1978. Cenozoic apes. In (V.J. Maglio & H.B.S. Cooke, eds.) *Evolution of African Mammals,* pp. 120-146, Harvard Univ. Press, Cambridge.

Simpson, G.G. 1960. Notes on the measurement of faunal resemblance. *Amer. J. Sci.,* 258-A: 300-311.

Singer, R. & L. Boné 1960. Modern giraffes and the fossil giraffids of Africa. *Ann. S. Afr. Mus.,* 45: 375-548, pl. 1-53.

_____ & _____ 1966. *Hipparion* in Africa. *Quaternaria,* 8: 187-191.

Skinner, M.F. & B.J. MacFadden 1977. *Cormohipparion* n. gen. (Mammalia, Equidae) from the North American Miocene (Barstovian-Clarendonian). *J. Paleontol.,* 51 (5): 912-926.

Smart, C. 1976. The Lothagam 1 Fauna: its phylogenetic, ecological, and biogeographic significance. In (Coppens Y., F.C. Howell, G.I. Isaac & R.E.F. Leakey, eds.) *Earliest Man and Environments in the Lake Rudolf Basin,* pp. 361-369, Univ. Chicago Press, Chicago.

Solounias, N. 1981. The Turolian Fauna from the Island of Samos, Greece, with special emphasis on the hyaenids and the bovids. *Contrib. Vertebr. Evolution,* 6, 1-232.

Szalay, F. & E. Delson 1979. *Evolutionary History of the Primates.* Academic Press, New York.

Tanaka, Y., T. Tarumi & K. Wakimoto (eds.) 1984. *Handbook of Personal Computer Assisted Statistic Analysis Part II Multivariate Analysis* (in Japanese). Kyoritsu Shuppan, Tokyo.

Tassy, P. 1983. Les Elephantoidea Miocènes du Plateau du Potwar, groupe de Siwalik, Pakistan. *Ann. Paléontol.,* 69 (2): 99-136, (3): 235-297, (4): 317-354.

_____ 1986. Nouveaux Elephantoidea (Mammalia) dans le Miocèna du Kenya. *Cahiers de Paléontologie, Travaux de Paléontologie Est-Africane.* 1-135, 18 pls.

Teilhard de Chardin, P. 1926. Description de mammiferes tertiaires de Chine et de Mongolie. *Ann. Paléontol.,* 15: 1-51.

_____ & C.C. Young 1930. Preliminary observations on the pre-Loessic and post-Pontian formation in western Shansi and northern Shensi. *Mem. Geol. Surv. China, Ser. A,* 8: 1-54.

_____ & _____ 1931. Fossil mammals from the late Cenozoic of northern China *Palaeontol. Sinica Ser. C,* 9 (1): 1-88.

Thenius, E. 1972. *Grundzüge der Verbreitungsgeschichte der Säugetiere, Eine Historische Tiergeographie.* Gustav Fisher Verlag, Stuttgart.

Thomas, H. 1979. Le role de barriere ecologique de la ceinture saharo-arabique au Miocene: arguments paleontologiques. *Bull. Mus. Natl. Hist. Nat. Ser. 4, 1, Sect. C,* 2: 127-135.

_____ 1981. Les Bovides miocenes de la formation de Ngorora du Basin de Baringo (Rift Valley, Kenya). *Proc. K. Ned. Akad. Wet. Ser. B,* 84 (3/4): 335-410.

_____ 1984. Les Bovidae (Artiodactyla: Mammalia) du Miocene du sous-continent Inden, de la

Peninsule Arabique et de l'Afrique:biostratigraphie, biogeographie et ecologie. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 45: 251-299.

_____, R. Bernor & J.-J. Jaeger 1982. Origines du peuplement mammalien en Afrique du nord durant le Miocene terminal. *Geobios,* 15 (3): 283-297.

Tobien, H. 1973a. On the evolution of mastodonts (Proboscidea, Mammalia) part 1: the bunodont trilophodont groups. *Notizbl. hess. L.- Amt Bodenforsch.*, 101: 202-276,pl. 23-26.

_____ 1973b. The structure of the mastodont molar (Proboscidea, Mammalia) part 1: the bunodont pattern. *Mainzer Geowiss. Mitt.*, 2: 115-147.

_____ 1978. On the evolution of mastodonts (Proboscidea, Mammalia) part 2: the bunodont tetralophodont groups. *Geol. Jb. Hessen,* 106: 159-208, pl. 10-21.

_____ 1980. Taxonomic status of some Cenozoic mammalian local faunas from Mainz basin. *Mainzer Geowiss. Mitteil.*, 9: 203-235.

Tsuchi, R. 1986. Recent progress in Neogene biochronostratigraphy (in Japanese). *J. Geography,* 95 (7): 76-83.

Wagner, A. 1857. Neue Beiträge zur Kenntnis der fossilen Säugetierüberreste von Pikermi. *Abh. math.-phys. Kl. Bayer. Akad. Wiss.*, 8.

Wenz, W. 1921. *Das Mainzer Becken und seine Randgebiete.* Heidelberg.

_____ 1931. Zur Stratigraphie und Tektonik der jüngeren Ablagerungen des Mainzer Beckens. *Geol. Rundsch.*, 22.

Whintworth, T. 1958. Miocene ruminants of East Africa. *Fossil Mammals of Africa,* 15: 1-50.

White, T.D. & J.M. Harris 1977. Suid evolution and correlation of African hominid localities. *Science,* 198: 13-21.

Wilkinson, A.F. 1976. The lower Miocene Suidae of Africa. *Fossil Vertebr. Africa,* 4: 173-282.

Williams, L.A.J. & G.R. Chapman 1986. Relationships between major structures, salic volcanism and sedimentation in the Kenya Rift from the equator northwards to Lake Turkana. In (L.E. Frostick, R.W. Renaut, I. Reid & J.-J. Tiercelin, eds.)*Sedimentation in the African Rifts, Geol. Soc. Special Publ.*, 25, pp. 59-74, Blackwell, Oxford.

Wood, A.E. 1968. Early Cenozoic mammalian faunas Fayum Province, Egypt. part II: the African Oligocene Rodentia. *Bull. Yale Peabody Mus. Nat. Hist.* 28: 29-105.

Woodburne, M.O. & R. L. Bernor 1980. On superspecific groups of some old world hipparionine horses. *J. Paleontol.*, 54 (6): 1319-1348.

Yen, F.-L., H.-J. Du & Beijing Graduate School of Wuhan Geological University (eds.) 1984. *Cenozoic Biostratigraphy of China* (in Chinese). Geological Press, Beijing.

Zdansky, O. 1930. Die alttertiären Säugetiere Chinas nebst stratigraphischen Bemerkungen. *Palaeontol. Sinica Ser. C,* 6 (2): 1-87, 5 pls.

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Appendix 1. Total taxa of Afro-Eurasian faunas

Taxa / Site	NM	AA	KG	NG	NE	NW	NK	LK	MP	SB	BH	ML	EP	PK	SM	MG	CJ	NR	DP	BD	YS	DD
Insectivora																						
Soricidae gen. et sp. indet.										1								1				
Crocidurinae																						
Erinaceidae																						
Galerix atticus														1	1							
Galerix modelingensis														1								
Talpidae																						
Desmanella dubia														1								
Chiroptera																						
Vesperitilionidae																						
Samonycteris majori															1							
Lagomorpha								1														
Ochotonidae																						
Alilipus sp.														1								
Leporidae																						
Proloagus cf. crusafonti														1								
Rodentia																						
Rhizomyidae gen. et sp. indet.																	1					
Kanisamys sivalensis																		1	1			
Kanisamys sp.							1															
Rhizomyoides sp.																		1	1			
Sciuridae gen. et sp. indet.																		1				
cf. Atlantoxerus getulus										1												
Spermophilinus cf. bredai															1							
Spermophilinus sp.																						1
Pliopetaurista breessana																						1
Pliopetes sp.																						1
Blackia sp.																						1
Miopetaurista sp.																						1
Ctenodactylidae																						
Sayimys sp.										1												
Castoridae																						
Sinocastor cf. zdanskyi																				1	1	
Dipoides problematicus																						1
Palaeomys castoroides																						1
Palaeomys plassi																						1
Trogonotherium minutum rhenanum																						1
Castor neglectus																						1
Cricetidae																						
Byzantina hellenicus															1							
Byzantina pikermiensis														1								
Copemys sp.																	1					
Kowalskia cf. lavocati														1								1
Megacricetodon sp.																	1					
aff. Myocricetodon cherifensis										1												
Prosiphneus murinus																					1	
Protatera yardangi										1												
Pseudomeriones pythagorasi															1							
Epimeriones austriacus																						1
Collimys cf. primus																						1
Crocetulodon sp.																						1
Muridae																						
Antemus chinjiensis																	1					
?Gerboa sp.																1						
cf. "Mastomys" colberti																		1				
Occitanomys ? neutrum														1								
Occitanomys ? provocator														1	1							
Parapodemus gaudryi														1								
Parapodemus lungduensis																						1
Parapodemus sp.																		1				
Pliospalax cf. sotirisi															1							
Progonomys sp.										1												

(cont.)

(**Appendix 1.** cont.)

Site	NM	AA	KG	NG	NE	NW	NK	LK	MP	SB	BH	ML	EP	PK	SM	MG	CJ	NR	DP	BD	YS	DD
Progonomys sp. nov.																		1				
Hystricidae																						
Hystrix primigenia														1	1							
Hystrix sp.								1									1		1			
Gliridae gen. et sp. indet.																		1				
Muscardinus vireti																						1
Muscardinus sp.														1								
Myomimus cf. dehmi														1								
Glis cf. minor																						1
Microdyromys sp.																						1
Steneofiber jageri													1									
Anomalomydae																						
Prospalax petteri																						1
Pterospalax sp.																						1
Zappodidae																						
Sminthozapus sp.																						1
Thryonomidae																						
Paraphiomys pigotti		1																				
Paraphiomys sp.	1																					
Paraulacodus sp.	1																					
Primates																						
Lorisidae gen. et sp. indet.																		1				
Hominoidea gen. et sp. indet.							1			1												
cf. Gigantopithecus sp.																		1				
Proconsul sp.		1																				
Kenyapithecus cf. africanus		1																				
Ramapithecus punjabicus																	1	1				
Sivapithecus sivalensis																	1	1				
Sivapithecus indicus																	1	1				
Hominoidea gen. et sp. nov.	1																					
Hominoidea small form				1																		
Hominoidea large form				1																		
Hominidae gen. et sp. indet.								1														
Pliohylobates eppelsheimensis													1									
Cercopithecoidea gen. et sp. indet.				1				1											1			
Colobinae gen. et sp. indet.				1			1															
cf. Libypithecus sp.										1												
Macaca sp.										1												
Mesopithecus pentelici														1		1						
Microcolobus tungenensis						1																
Cetacea																						
Delphinidae																						
cf. Lagenorhynchus										1												
Platanistidae gen. et sp. indet.										1												
Creodonta																						
Hyaenodontidae																						
Dissopsalis carnifex																	1					
cf. Isohyaenodon sp.																		1				
Hyainailouros bugtiensis																	1					
Carnivora																						
Family indet.																						
Agnotherium sp.				1																		
Amphicyonidae																						
Amphicyoninae large form																	1					
Amphicyon palaeoindicus																	1	1				
Vishnucyon chinjiensis																	1					
Ursidae																						
Agriotherium cf. africanum										1												
Simocyon primigenium														1							1	
Simocyon diaphorus													1								1	
Hyaenarctis sp.																					1	
Indarctos atticus										1				1	1	1						

(cont.)

(**Appendix 1.** cont.)

Site	NM	AA	KG	NG	NE	NW	NK	LK	MP	SB	BH	ML	EP	PK	SM	MG	CJ	NR	DP	BD	YS	DD
Indarctos lagrelii																				1		
Indactoos sinensis																				1		
Ursavus cf. depereti															1							
Mustelidae gen. et sp. indet.							1															
Mustelinae gen. et sp. indet.																		1				
?Enhydriodon laticeps														1								
?Enhydriodon sp.														1								
Eomellivora sp.				1														1				
Eomellivora wimani																				1		
Lutra aonychoides																				1	1	
Martes lydekkeri																	1					
Martes palaeosinensis																				1	1	
Martes woodwardi														1								
Martes cf. sansaniensis																						1
Martes sp.																1	1	1				1
Melodon incertum																				1		
Melodon major																				1		
Parataxidea crassa																				1		
Parataxidea maraghana															1	1						
Parataxidea polaki																1						
Parataxidea sinensis																				1		
Plesiogulo brachygnathus																				1	1	
?Plesiogulo sp.														1								
Promephitis alexejewi																				1		
Promephitis lartetii														1	1							
Promeles palaeattica														1	1	1						
Promeles sp.																						1
Proputorius minimus																				1		
Sinictis dolichognathus																				1		
Sinictis pentelici														1								
Sivaonyx bathygnathus																		1				
Sivaonyx sp.				1																		
Vishnuonyx chinjiensis																	1					
Pcocyonidae																						
Sivanasua himalayensis																		1				
Viverridae																						
Viverriae gen. et sp. indet.																		1				
?Herpestinae sp.																		1				
Herpestes guerini												1										
cf. Ichneumia sp.								1														
?Progenetta sp.																		1				
?Viverra chinjiensis																	1					
Viverra sp.										1												
Hyaenidae gen. et sp. indet.	1			1						1							1	1				
Crocuta sp.								1														
Euryboas sp.										1												
Hyaena algeriensis											1											
Hyaena honanensis																				1		
Hyaena variabilis																				1		
Hyaenictis (Percrocuta) eximia										1		1		1	1	1						1
Hyaenictis graeca														1								
Percrocuta tobieni				1																		
Hyaenictitherium sp.										1												
Hypcrhyaena leakeyi							1															
Ictitherium gaudryi																				1	1	
Ictitherium hyaenoides																				1		
Ictitherium sinensis																				1		
Ictitherium viverrinum														1	1							
Ictitherium wongi																				1		
Ictitherium robustum													1									
Lycyaena dubia																				1		
?Miohyena sp. nov.																		1				

(cont.)

(**Appendix 1.** cont.)

Site	NM	AA	KG	NG	NE	NW	NK	LK	MP	SB	BH	ML	EP	PK	SM	MG	CJ	NR	DP	BD	YS	DD
Palyhyaena sivalensis																		1				
Percrocuta carnifex																	1	1	1			
Percrocuta gigantea																		1	1			
Percrocuta grandis																		1				
Percrocuta pentelici												1										
Percrocuta senyueki										1												
Plioviverrops orbignyi														1	1							
Thalassictis hyaenoides														1	1							
Thalassictis wongii												1			1	1						
Thalassictis (Lycyaena) chaeretis														1	1							
Thalassictis (Lycyaena) sp. nov.														1	1							
Felidae gen. et sp. indet.								1									1					
Felis attica														1	1	1						
Felis sp.														1							1	
Homotherium palanderi																				1	1	
Homotherium tingi																				1		
Metailurus parvulus														1	1	1						
Metailurus major														1	1							
Pseudaeiurus major																				1	1	
Pseudaelurus minor																				1	1	
Pseudaeiurus turnauensis																						1
?Sansanosmilus sp.																	1					
Sivaelurus chinjiensis																	1					
'Sivasmilus'(Paramachaerodus)copei																	1					
? Sivaelurus sp.																		1				
Megatereon praecox																		1				
Vinayakia nocturna																		1				
Pontosmilus ogygius													1									
Machairodontinae gen. et sp. inde	1																	1				
Machairodus aphanistus												1										
Machairodus giganteus														1	1	1						
Machairodus cultridens													1									
Machairodus trancliensis																						1
Machairodus sp.										1												
Machairodus sp. A(Paramachaerodus aff. orientalis)										1												
Machairodus sp. B										1												
Machairodus sp. C										1												
Paramachairodus orientalis														1		1						
Felidarm inc. subfam.																						1
Canidae gen. et sp. indet.								1														
Canidae small form				1																		
Phocidae																						
aff. Monachinae gen. et sp. indet.										1												
Tubulidentata																						
Orycteropodidae		1																				
Orycteropus browni																		1				
Orycteropus chemeldoi				1																		
Orycteropus gaudryi															1	1						
Orycteropus pligrimi																		1				
Orycteropus sp.								1									1					
Proboscidea																						
Palaeomastodontidae																						
Mammut borsoni														1	1							
Gomphotheriidae gen. et sp. indet.																	1	1	1			
Gomphoterium angustidens													1									
Gomphoterium angustidens var. subtapiroidea													1									
Gomphoterium gigantorostris													1									
Amebelodon cyrenaicus										1												
Anancus cuneatus																					1	
Anancus sinensis																					1	
Anancus sp.								1														
Archaeobelodon cf. filoholi		1																				

(cont.)

(**Appendix 1.** cont.)

Site	NM	AA	KG	NG	NE	NW	NK	LK	MP	SB	BH	ML	EP	PK	SM	MG	CJ	NR	DP	BD	YS	DD
Choerolophodon ngorora				1	1		?															
Choerolophodon pentelici														1	1	1						
Selenolophodon spectabilis																					1	
Tetralophodon exoletus																				1	1	
Tetralophodon longirostris																						1
Tetralophodon longirostris var. dubius													1									
Tetralophodon longirostris var. grandis													1									
Tetralophodon sp. nov.	1																					
Tetralophodon sp.				1																	1	
Stagodontidae																						
Stegodon licenti																					1	
Stegodon yushensis																					1	
Elephantidae																						
Primelephs sp.								1														
Stegotetrabelodon grandincisivus														1	1							
Stegotetrabelodon lybicus										1												
Stegotetrabelodon sp.								1	1													
Deinotheriidae gen. et sp. indet.																	1	1	1			
Deinotherium bozasi					1	1	1															
Deinotherium cf. giganteum													1	1	1							1
Deinotherium sp.	1							1										1				
Prodeinotherium hobleyi				1																		
Prodeinotherium sp.		1																				
Hyracoidea																						
Procaviidae																						
Megalohyrax championi		1																				
Parapliohyrax sp.				1	1																	
Pliohyrax graecus														1	1							
Pliohyrax kruppii															1							
Sirenia																						
Dugongidae																						
Metaxytherium serresii										1												
Perissodactyla																						
Equidae(Hipparionine)																						
Hipparion cf. africanum	1				1	1	1			1	1											
Hipparion (Cremohipparion) licenti																					1	
Hipparion (Hipparion) dermatorhinum																				1	1	
Hipparion dietrichi															1	1						
Hipparion (Hipparion) fossatum																				1		
Hipparion (Hipparion) hippidiodus																				1		
Hipparion (Plesiohipparion) houfenense																					1	
Hipparion matthewi														1	1							
Hipparion minus														1	1	1						
Hipparion (Probosidipparion) pater																					1	
Hipparion proboscideum														1	1							
Hipparion (Hipparion) platyodus																					1	
Hipparion cf. sitifense								1		1												
Hipparion turkanense								1	1													
Hipparion (Cremohipparion) forstenae																				1		
Hipparion (Hipparion) placodus																				1		
Hipparion (Probosidipparion) sinensis																					1	
Hipparion (Baryhipparion) insperatum																					1	
Hipparion (Baryhipparion) cf. tchicoicum																					1	
Hipparion large form														1	1	1						
Hipparion small form																						
Cormohipparion perimense																		1				
Hipparion prostylum												1										
Hipparion antilopinum																			1			
Hipparion nagriensis																		1				
Hipparion theobaldi																		1	1			
Hipparion primigenium													1									
Hipparion sp.																	1					

(cont.)

(**Appendix 1.** cont.)

Site	NM	AA	KG	NG	NE	NW	NK	LK	MP	SB	BH	ML	EP	PK	SM	MG	CJ	NR	DP	BD	YS	DD
Anchitherium sp. (Anchitheriinae)													1									
Chalicotheriidae gen. et sp. indet.	1							1														
Ancylotherium pentelicum															1	1						
Chalicotherium goldfussi													1	1								
Chalicotherium salinum																	1	1				
Macrotherium salinum																	1	1				
Tapiridae																						
Tapirus teilhardi																					1	
Rhinocerotidae gen.et sp. indet.		1															1					
Aprotodon fatehjangense																	1	1				
Brachypotherium lewsi				1					1													
Brachypotherium perimense																	1	1	1			
Brachypotherium goldfussi													1									
Paradiceros sp.	1																					
Aceratheriinae																						
Aceratherium incisivum													1	1								
Aceratherium sp.				1								1					1					
Chilotheridium pattersoni				1																		
Chilotheridium sp.	1								1													
Chilotherium anderssoni																				1		
Chilotherium gracile																				1		
Chilotherium habereri																				1		
Chilotherium intermedium intermedium																	1	1				
Chilotherium intermedium companatum																			1			
Chilotherium kowalewski															1							
Chilotherium persiae																1						
Chilotherium planifrons																				1		
Chilotherium samium															1							
Chilotherium schlosseri															1							
Chilotherium wimani																				1		
Rhinocerotinae																						
Ceratotherium sp.								1														
Dicerorhinus orientalis																				1	1	
Dicerorhinus palaeosinensis																				1	1	
Dicerorhinus schleiermacheri												1	1	1	1							
Dicerorhinus belvederensis													1									
Dicerorhinus sp.				?							1						1	1				
Diceros neumayri										1												
Diceros pachygnathus														1	1	1						
Rhinoceros broeni																	1					
Rhinoceros cf. sivalensis																			1			
Rhinoceros vidali																		1				
Iranotheriinae (Elasmotheriinae)																						
Caementodon oettingenae																	1	1				
Iranotherium morgani																1						
Kenyatherium bishopi	1						1															
Sinotherium lagrelii																				1		
Artiodactyla																						
Suidae																						
Chleuastochoerus stehlini																				1	1	
Conohyus chinjiensis																	1					
Conohyus indicus																		1				
Conohyus sindiense																	1	1				
Conohyus sp.				1														1				
Dicoryphochoerus haydeni																	1	1				
Dicoryphochoerus robustus																		1				
Dicoryphochoerus sp.																		1				
Dorcabune nagrii																	1					
Hippophyus deterrai																		1				
Hippopotamodon sivalense(Dicryphochoerus titan)																		1				
Libicochoerus sp. nov.		1																				
Listoriodon pentapotamiae																	1	1	1			

(cont.)

(**Appendix 1.** cont.)

Site	NM	AA	KG	NG	NE	NW	NK	LK	MP	SB	BH	ML	EP	PK	SM	MG	CJ	NR	DP	BD	YS	DD
Listoriodon sp.													1									
Lophochoerus himalayensis																		1				
Lophochoerus nagrii																		1				
Lophochoerus sp.																	1					
Lopholistriodon kidogosana				1																		
Merycopotamus pusillus																	1					
Microstonyx erymanthius												1		1	1	1						
Nyanzachoerus cf. devauxi										1	1											
Nyanzachoerus kanamensis	1									1												
Nyanzachoerus syrticus										1												
Nyanzachoerus tulotos	1							1														
Nyanzachoerus sp.						1	1															
Paleochoerus perimensis																	1	1				
Potamochoerus hytheriordes															1							
Potamochoerus hytheriordes																				1		
Propotamochoerus hysudricus																		1				
Propotamochoerus salimus																	1	1	1			
Propotamochoerus sp.																		1				
Sus advena																		1				
Sus erymanthius																				1	1	
Sus antiquus													1									
Sus sp.														1								
Tetraconodon minor																		1				
Tetraconodon sp.																		1				
Tayassuidae gen. et sp. indet				1																		
Hemimerix sp.		1																				
Schizochoerus sp.																		1				
Anthracotheriidae																						
Hemimeryx pusillus																	1	1				
Merycopotamus dissimilis																		1	1			
Merycopotamus petrocchii										1												
Merycopotamus namus																		1				
Hippopotamidae																						
Hexaprotodon sahabiensis										1												
Hippopotamus (Hexaprotodon) sp.			1					1	1													
Kenyapotamus coryndoni	1			1	1	1																
Kenyapotamus sp.							1															
Tragulidae gen. et sp. indet.	1																1					
Dorcatherium chappusi		1																				
Dorcatherium majus																	1	1	1			
Dorcatherium minus																	1	1	1			
Dorcatherium naui													1		1							
Dorcatherium pigotti		1		1		1																
Dorcatherium sp.																	1	1	1			
Dorcabune anthracotherioides																	1					
Dorcabune nagrii																	1	1	1			
Dorcabune sp.																		1				
Sanitheriidae																						
Diamantohyus africanus		1																				
Climacoceriidae																						
Climacoceras gentryi		1		1																		
Cervidae gen. et sp. indet. large form														1								
Axis speciosus																					1	
Cervavitus demissus																					1	
Cervavitus novorossiae																				1	1	
Eostyloceros blainvillei																					1	
Eostyloceros triangularis																					1	
Muntiacus sp.															1							
Pliocervus pentelici														1	1	1						
Procapreolus latifrons																				1	1	
Giraffidae																						
Giraffa sp.								1														

(cont.)

(**Appendix 1.** cont.)

Site	NM	AA	KG	NG	NE	NW	NK	LK	MP	SB	BH	ML	EP	PK	SM	MG	CJ	NR	DP	BD	YS	DD
Giraffokeryx punjabiensis																	1	1				
Giraffokeryx sp.																	1					
Helladotherium duvernoyi														1	1	1						
Helladotherium sp. nov.															1							
Honanotherium atticum														1		1						
Honanotherium schlosseri																					1	
Honanotherium speciosum														1	1							
Hydaspitherium megacephalum																		1	1			
Palaeotragus coelophrys															1	1				1		
Palaeotragus decipiens																					1	
Palaeotragus microdon																				1		
Palaeotragus rouenii														1	1							
Palaeotragus primaevus				1	1	1	?															
Palaeotragus sp. nov.	1																					
Palaeotragus sp.																					1	
Samotherium boissieri															1	1						
Samotherium sinense																				1		
Samotherium sp.	1			1						1												
cf. Sivatherium sp.																		1				
?Walangania africanus		1																				
Bovidae																						
Dorcadoryx triguetricornis																					1	
Homoiodorcas tungenium				1																		
Kubanotragus sokolovi																	1					
Leptobos syrticus										1												
Helicoportax tragelaphoides																	1	1				
Helicoportax praecox																	1	1				
Pachyportax latidens																		1	1			
Pachyportax sp.																		1				
Paraprotoryx minor																				1		
Paraprotoryx killgusi																					1	
Plesiadax depereti																				1		
Plesiadax minor																				1		
Protragocerus gluten																	1					
Protragocerus labidotus				1																		
Sinoryx bombifrons																					1	
Strepsipotax sp.																	1					
Sivaceros cf. gradiens																	1	1	1			
Sivoreas eremita				?		?											1					
Tragocerus browni																		1	1			
Tragocerus gregarius																				1		
Tragocerus lagrelii																				1		
Tragocerus laticornis																					1	
Tragocerus punjabicus																		1	1			
Tragocerus spectabilis																				1		
Alcelaphini gen. et sp. indet.								1	1													
cf. Aepycerus sp.								1														
cf. Damalacra sp.										1												
Antilopini gen. et sp. indet.								1	1		1											
Antidorcas sp.				1		1																
Gazella altidens																				1		
Gazella capricornis														1	1							
Gazella deperdita																1						
Gazella dorcadoides															1					1		
Gazella gaudryi																				1	1	
Gazella lydekkeri																	1	1	1			
Gazella mytilinii															1							
Gazella paotehensis																				1		
Gazella sp.	1							1		1							1	1				
Oioceros atropatenes																1						
Oioceros rodleri																1						
Oioceros rothi														1		1						

(cont.)

(**Appendix 1.** cont.)

Site	NM	AA	KG	NG	NE	NW	NK	LK	MP	SB	BH	ML	EP	PK	SM	MG	CJ	NR	DP	BD	YS	DD
Oioceros wegneri															1							
Oioceros sp.				1		1															1	
Oiuzoceros sp.	1																					
Prosinotragus kuhkmanni															1							
Prosinotragus sp. nov.															1							
Prostrepsiceros houtumschindleri var. A															1							
Prostrepsiceros houtumschindleri var. B																1						
Prostrepsiceros (P.) libycus										1												
Prostrepsiceros rotundicornis var. A													1									
Prostrepsiceros rotundicornis var. B															1	1						
Protragelaphus skouzesi													1		1							
Sinotragus crassicornis															1							
Sinotragus wimani																				1		
Sinotragus sp. nov.																1						
Boselaphini gen. et sp. nov.																		1				
Cephalophini gen. et sp. indet.								1														
Hippotragini gen. et sp. indet.						1	1	1	1													
Hippotragus sp.										1												
Miotragocerus-Tragoportax Complex																						
Miotragocerus cyrenaicus										1												
Miotragocerus gradiens																	1					
Miotragocerus monacensis var. A													1	1								
Miotragocerus monacensis var. B													1	1	1							
Miotragocerus punjabicus																		1				
Miotragocerus valenciennesi													1	1								
Miotragocerus sp.	1																					
Samokeros minotaurus var. A															1	1						
Samokeros minotaurus var. B															1							
Tragoportax amalthea													1	1								
Tragoportax curvicornis															1							
Tragoportax rugosifrons													1	1								
Tragoportax salmontanus																			1			
Tragoportax sp.																		1				
Neotragini gen. et sp. indet.								1														
Raphicerus sp.										1												
Ovibovini gen. et sp. indet.																						
Criotherium argalioides															1							
Palaeoreas lindermayeri													1	1								
Palaeoreas sp.				?		?																
Parurmiatherium rugosifrons															1							
Urmaitherium intermedium																				1		
Urmiatherium polaki																1						
Palaeoryx-Protoryx Complex																						
Palaeoryx pallasi var. A													1									
Palaeoryx pallasi var. B															1							
Palaeoryx pallasi var. C													1	1								
Palaeoryx pallasi var. D													1	1								
Protoryx carolinae													1									
Protoryx crassicornis var. A															1	1						
Protoryx crassicornis var. B															1	1						
Protoryx laticeps var. A															1	1						
Protoryx laticeps var. B															1	1						
Protoryx laticeps	1																					
Protoryx sp.				1																		
Protoryx shansiensis																				1		
Protoryx bohlini																					1	
Protoryx yuchensis																					1	
Pseudotragus capricornis															1							
Pseudotragus ? gentryi				1	1																	
?Pseudotragus potwaricus																	1					
?Pseudotragus sp.																		1				
Sporadotragus parvidens														1	1							

(cont.)

(**Appendix 1.** cont.)

Site	NM	AA	KG	NG	NE	NW	NK	LK	MP	SB	BH	ML	EP	PK	SM	MG	CJ	NR	DP	BD	YS	DD
Tragoreas oryxoides															1							
Tragoreas palaeosinensis																					1	
Pachytragus aff. solignaci				1																		
Reduncini gen. et sp. indet.						?	?	1														
Redunca aff. darti										1												
Rupicaprini gen. et sp. indet.															1							
Tragelaphini gen. et sp. indet.								1	1													
Selenoportax lydekkeri																		1	1			
Selenoportax vexillarius																		1				
Selenoportax sp.														1				1				
Total Number of Taxa	23	14	1	33	7	10	11	29	9	44	5	9	22	73	85	42	66	95	28	60	51	30

NM; Namurungule, AA; Aka Aiteputh, KG; Kongia, NG; Ngorora, NE; Ngorora upper E, NW; Ngeringerowa NK; Nakali, LK; Lukeino, MP; Mpesida, SB; Sahabi, BH; Bou Hanifia, ML; Mt. Lebéron, EP; Eppelsheim PK; Pikermi, SM; Samos, MG; Maragheh, CJ; Chinji, NR; Nagri, DP; Dhok Pathan, BD; Baode, YS; Yushe DD; Dorn-Dürkheim.